IoT-Based Temperature Monitoring for Milk Collection Tank in Remote Area

Setyawan P. Sakti[1(✉)], Triswantoro Putro[1], Dewi Anggraeni[1], Agus Naba[1], and Vany R. Wijayanto[2]

[1] Department of Physics, Brawijaya University, Jl. Veteran, Malang 65145, Indonesia
sakti@ub.ac.id

[2] PT ESP Dinamika, Dukuh Kupang Barat 32/41, Surabaya 60225, Indonesia

Abstract. Monitoring the temperature of the milk collection tank in the milk collection plan is a necessary effort to achieve good milk quality indicated by lower bacterial content. The tank's temperature must reach below 4 °C in less than two hours after the last fresh milk input. Internet of Things (IoT) for temperature measurement enables real-time remote monitoring and visualization of the tank temperature. This paper presents a low-cost IoT temperature monitoring using the available electronic module in the market. With a data rate and remote location, the IoT system is developed based on 2G wireless sensor network. Using the electronic module, available mobile network and cloud storage enabled easy implementation of the IoT system. The developed system stores and provides real-time data which is accessible anywhere. The experimental results show that the developed system has an error rate of 0.14%. The real-time data of the milk collection tank temperature was successfully recorded and displayed. The pattern of the milk collection tank temperature can be observed from the collected data showing the tank's cooling process and the temperature regulation of the milk collection tank. The results show that implementation of the IoT monitoring system in remote area to improve the data availability is possible.

Keywords: internet of things · monitoring · temperature

1 Introduction

The milk industry is part of the green economy. In 2021, the demand for raw materials for milk in Indonesia was around ±4.19 million tons (equivalent to fresh milk), an increase of 8.5% from 2020. Domestic raw materials for milk are 21%, and the remaining 79% are imported. 93% of the domestic milk supply comes from smallholder farmers. The milk from the farmer is collected in a milk collection point. After the quick quality screening, the fresh milk is stored in a cooled milk collection tank to maintain the quality. The milk must be cooled down immediately [1]. Cooling the milk below 4 °C inhibits the bacteria growth in the milk [2–4]. Therefore, in good management practice, it is essential to guarantee that the milk collection tank's temperature quickly reaches the target temperature and maintains the temperature under the specific value until the milk is discharged to the transportation tank [5–7].

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The temperature of the milk must be below 8 °C in less than one hour. Within two hours from the last fill of milk into the tank, the temperature must be below 4 °C after two hours [8]. The temperature is then kept below 8 °C until the time the milk is taken for delivery to the factory. Based on the condition scenario, the temperature variation of the milk collection tank ranges from -5 °C to 40 °C. The 40 °C is the possible maximum temperature in the milk collection point area. The milk depositing time from the farmer to the milk collection plant is twice a day. In the morning, it starts around 06:30 and finishes around 08:00. In the afternoon, milk deposits are from around 15:30 to 16:30. The milk is taken from the collection tank to be transported to the factory at around 10:00 AM.

The existing tank has been equipped with a temperature control system, but there is still a problem with the tank temperature due to various conditions. The aging of the controller and milk tank caused a controlling error, requiring redundant temperature monitoring. The human resource quality and discipline lead to improper setting of the cooler. When there is a temperature error, the error is unnoticed, leading to the milk's decrease. This error was known too late because the temperature recording process was not carried out regularly, so when there were changes in the cooling behavior of the holding tank, it could not be detected immediately.

Temperature data recording is not available in the milk collection plan. The available data logger in the market still requires manual data collection from time to time. A real-time temperature recording solution is needed as a step in the digitization process and data integration from the milk collection tank to the factory to maintain the milk quality. Manually recording or offline data recording is ineffective because of the need for human resources and the broad area of the milk collection plant location. The distribution of the milk collection plant covers a radius of 200 km.

The use of IoT to monitor the tank temperature monitoring is one of many alternative solutions. It has been reported the use of IoT to monitor the milk temperature from milk collection centers to the factory [9]. The communication between the sensor node to the data server can be established using LoRa [10, 11], 3G [12], ZigBee [13], WiFi [14], GPRS [15], NB-IoT [16], GSM (2G) [17] and many other communication protocols [18]. The communication protocol selection depends on the data rate, distance, and IoT configuration. The location of the IoT for monitoring the temperature of the milk collection tank is in a rural area with limited internet access. In most locations, only a 2G mobile network is available.

In this experimental trial, the distance between the base transceiver station of the 2G mobile network and IoT nodes is 4 km (Fig. 1). In this paper, an IoT system design and testing are presented for real-time monitoring the milk collection tank's temperature. The system implementation using modular system composed of functional module to perform the monitoring tasks is not yet reported.

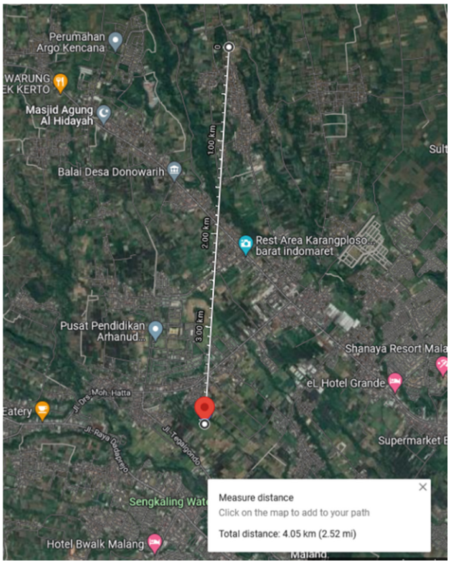

Fig. 1. Maps and distance between the IoT device and closes Base Tranceiver Station

2 Material and Method

The IoT design consists of hardware and software systems design. The precision and accuracy of the temperature sensor for monitoring the milk collection tank must be less than 0.5 °C. The microcontroller of the IoT should be low power, able to communicate to the cloud server, has local storage and a real-time timer. The system should work in battery mode and power line mode.

For this purpose, a PT-100 class A temperature sensor was selected. The sensor has an error of less than 0.2 °C in the temperature range from -5 °C to 30 °C. The accuracy and precision of the temperature monitoring are fulfilled. For the conversion process from PT-100 to the temperature value, a bridge module with MAX31865 signal conditioning is used. The MAX31865 has a 15-bit internal ADC system, so the theoretical temperature measurement resolution is 0.03125 °C.

The microcontroller uses the ESP32-WROOM-32E Module from Espressif. The module has an onboard WiFi antenna which can be used to configure the system through wireless communication. The GSM 2G communication module is used and implemented using a GSM Module SIM800 to communicate with the cloud database. The selection is based on the condition that the milk collection point is singularly distributed in a wide area, which is ineffective for connecting using LoRa.

The block diagram of the system is presented in Fig. 2. The ESP32 module is used as the main microcontroller system. Data communication with the mobile network is carried out using the SIM800L module through the UART communication between the ESP32 and the SIM800L. ESP32 with MAX31865 and the SD Card modules use SPI communication. The connection between the ESP 32 and the DS3231 module is using I^2C communication.

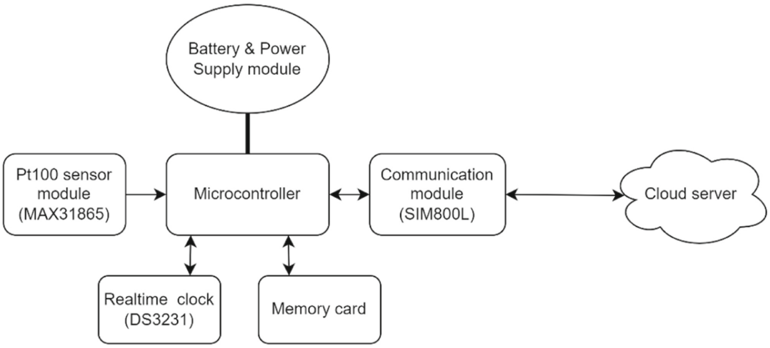

Fig. 2. System block diagram

The system is programmed to read the tank temperature every 10 min. The data length of each transmitted temperature data is 161 bytes. Theoretically, the maximum transfer speed of 2G is 5 kBps. Therefore, the transfer speed is adequate to transmit the data from the IoT node to the cloud server.

3 Results and Discussion

The temperature data and time are sent to the cloud storage (Alibaba Cloud) via the SIM800L module. The communication is using HTTP protocol which is sent sequentially using the AT-Command. The developed system has been tested in an area with the good mobile network coverage. The distance between the system and the BTS is less than 300 m in the 4G LTE network. The testing showed excellent results. Testing of sending data to the server did not experience any problems, and no data was lost.

The system was installed in the milk collection point for testing, as depicted in Fig. 3, and run for a month. The data in the cloud server and in the SD Card are compared. There is a systematic timestamp difference among the recorded data in the cloud server and the SD Card as the time setting of the DS3231 did not synchronize with the server. The data interval in the SD Card is precisely 10 min as it is programmed. However, the time interval between each data in the server varied from 00:09:49 to 00:10:13. The average interval is 10 min. The transmission speed from the IoT node to the cloud server is not constant. The fluctuated speed may come from the IoT node to the BTS or the BTS to the cloud server.

The data for June 2022 is presented in Fig. 4. Within 30 days, the received data from 1 June at 00:00:10 to 30 June at 24:00; the recorded data in the SD Card is 4320 data. The stored data in the cloud server is 4314 data. There were 6 data losses from 4320 data sent by the IoT node. It is equal to 0.14% of data loss. The value is much better than the reported data loss using LoRa [10], Zigbee [19], and WiFi [20] (Fig. 6).

There are 3 data points from a total of 4320 data (30 days with data sent every 10 min) which shows outlier data values. It is shown from 7 June to 9th and around 25 June. The time stamp and temperature of the outlier data are checked. It was found that the temperature data value is more than 300 °C. The data is confirmed by the data stored in

Fig. 3. System installation in the milk collection point

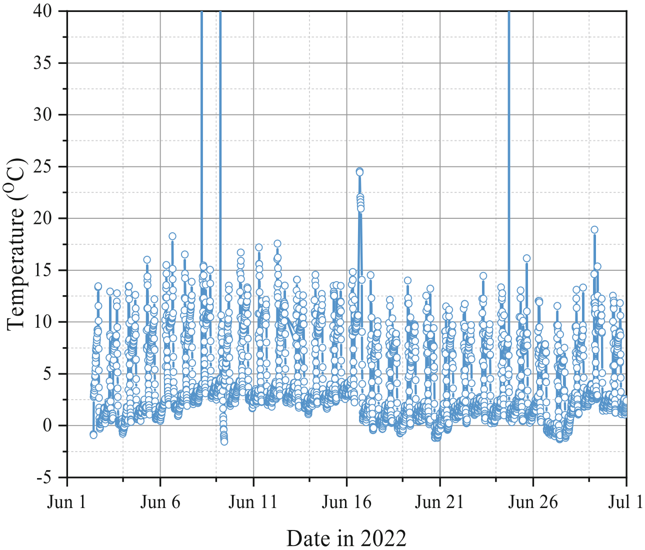

Fig. 4. Milk collection plan temperature in a month (June 2022) captured using the web application

the SD Card. It was found that the time stamp of the outlier data is around 5 min from the previous regular data. It means that the data is not originated from the reading data from the MAX31865 but arises from an unknown source. The transmission action is also unexpected.

Based on Fig. 3, it can be seen that there are variations in the minimum and maximum temperature changes each day. This temperature change can be observed in the variation of tank temperature in 1 week, as in Fig. 4. Details of tank temperature in one day can be seen, for example, in Fig. 5. Figure 4 and Fig. 5 show that the milk temperature is below 8 °C in less than 1 h since the last milk deposit (at 08:00 AM and around 16:00). The temperature is below 4 °C in less than 2 h and continues to be maintained below 4 °C during the storage time. The storage temperature fulfills the required temperature [3] for temporary storing to prevent bacterial growth. The storage time is between 08:00 and

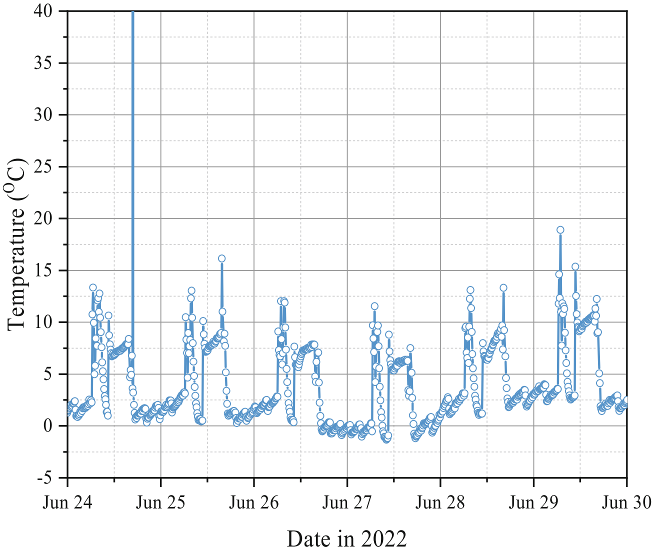

Fig. 5. Milk collection plan temperature in one week

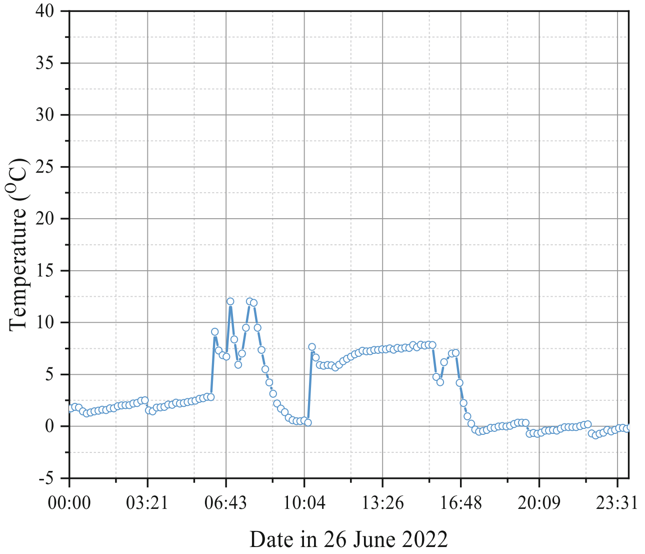

Fig. 6. Milk collection plan temperature in one day

the discharge time around 10:00, and from 17:00 to 06:30 on the following day during the second deposit period.

4 Conclusion

An IoT system for temperature monitoring system using ESP32 and GSM 2G data communication has been successfully developed. The IoT system can send the data to the cloud with a data loss of 0.14%. Data error indicated by outlier temperature data is less than 0.1%. The recorded data can show that the temperature control of the tank in the milk collection plan is still in good condition. The system shows that temperatures below 8 °C and 4 °C can be reached in less than the standard time. The data communication speed of the IoT to the cloud server is varied.

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