Design of a water level and river discharge monitoring system using internet of things (IoT) technology

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ABSTRACT

River hydrometric surveys with Internet of Things (IoT) technology can be conducted using water level sensors equipped with LoRa communication capabilities. The sensors are placed in strategic locations along the river and measure the water level periodically. The data is then transmitted using LoRa technology to a central station or gateway located on land. The central station collects and processes data from all sensors, providing real-time water level readings for the entire river area. This data can be used for various purposes, including flood monitoring, navigation, and water management. The utilisation of this technology can be an alternative to conventional hydrometric activities. In this research, a prototype water level and river discharge monitoring system with IoT has been built. The method approach is experimental. In addition, system and integrity testing shows the success of nodes sending data packets and the gateway is able to receive data packets from nodes. Meanwhile, the implementation of monitoring where ThingSpeak as a server can display graphs in real time measurements made by the node. The system monitoring results show that the average water level of Lambidaro River reaches 121 cm (min) and 125 cm (max). Meanwhile, the water discharge of Lambidaro River reached 0.8 m3/s (min) and 1.3 m3/s (max). Measurement of both variables took place within a period of 3.5 hours.

Keywords: river, hydrometry, Wireless Sensor Network, LoRa, IoT

I. Introduction

Hydrometric measurements are very important today as global climate change and increased human activities have affected the hydrological cycle in many parts of the world (Shahzad and Riphah, 2012). Accurate and continuous hydrometric measurements are essential for understanding how such changes affect the water cycle. In addition, hydrometric measurements are essential in hydrological modelling, water resources management, flood control, irrigation planning, water transport safety, and overall water environment condition monitoring.

In general, one of the hydrometric measurement activities is the installation of hydrometric equipment (Akrom and Agustiani, 2018). In this activity, which is carried out in the form of measurement and monitoring, the installation of hydrometric equipment at water measurement stations, flow velocity meters, and water level sensors. However, in the field there are often several shortcomings of this conventional method, including: limited time, limited number of measurements, human error, depending on the weather, and limited range.

Based on the above problems, it is necessary to create a system that can easily perform hydrometric measurements effectively (wide measurement range and real-time) and efficiently (low cost). A quite realistic approach is the use of the Internet of Things (IoT) in hydrometric survey activities, mainly including the measurement of water surface height and river discharge.

IoT (Internet of Things) is a technological concept where objects connected to the internet can communicate and exchange data without human interaction (Susanto, et al., 2022). In IoT, objects are packed with sensors, software and networks that allow them to connect, interact, and exchange information with the internet network. In practice, IoT can be used to capture data from surrounding objects and send it to analytics platforms for processing and decision-making. Within the IoT

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technology itself, there are sensor network platforms (Wireless Sensor Network) and communication platforms (Long-Range).

Wireless Sensor Network (WSN) and LoRa (Long Range) are two related technologies in terms of wireless communication (Esyaganitha, et al., 2021). WSN is a wireless sensor network consisting of sensors that are interconnected and can collect data from the surrounding environment (Nurkhamid and Widodo, 2021). LoRa is a long-range wireless communication technology that enables data transmission over long distances with low power consumption (Sun et al., 2020).

When used together, LoRa is used as a wireless communication protocol to connect sensors in a WSN network (Hakim, et al., 2012). LoRa enables data transmission over long distances with low power consumption, making it ideal for use in WSN networks consisting of many sensors spread across a wide area. In hydrometric applications, for example, sensors connected in a WSN network can be used to measure water flow and water level in rivers and lakes, and the collected data can be transmitted via LoRa to a control centre for analysis and management.

By using LoRa in a WSN network, hydrometric data collection can be automated, accurate, and efficient. This allows responsible parties to monitor the condition of the water environment continuously and take appropriate actions to maintain a good balance of the water ecosystem.

Therefore, the focus of this research lies on the design of IoT technology in monitoring the water level and river discharge. In making the device, there are several uses of devices such as ultrasonic sensors, GPS, microcontrollers, transmitters and receivers, as well as devices related to communication.

II. Related Work

Several previous studies have discussed water resources management, especially in monitoring water levels. Verma, et al (2015) presented a system to monitor water levels on campus in 2015. The system uses low-cost ultrasonic sensors capable of measuring distances up to 10 metres. To communicate between tanks located at great distances, the system uses a sub-GHz communication network. The system consists of three main components: gateways, end nodes, and relay nodes. Data from other nodes is received by the gateway and sent to the cloud server. The end nodes connected to the sensors wake up regularly and transmit the recorded values to the gateway. Relay nodes are upgraded end nodes that can forward values from other end nodes. The system has a range of 10 m and an accuracy of 1.5%.

Robles et al. (2015) presented an IoT-based smart water management model in 2015. For process control, this model uses OPCUA (Object Linking and Embedding for Process Control Unified Architecture). The model consists of three main modules: water management, general communication, and coordination subsystem interface. Then, an implementation scenario in Aula Dei, an experimental station on the island of Zaragoza, is described. The study concludes that the use of IoT devices for water monitoring and governance has wider implications.

Perumal et al. (2016), demonstrated an IoT-based system for real-time monitoring of water levels in smart homes, sensor actuators, power sources, and wireless connectivity comprise the system. The measurement values are sent to an internet cloud server and displayed on a remote dashboard. Notifications are also sent to a Twitter account. For measurement, the system uses an ultrasonic range server and a water sensor. The proposed system uses ATmega328P controller board. One sensor feed cycle takes 126 ms to complete the system. During the experiment, 500 readings were taken. The implemented system is very simple, consisting of an IoT device with sensors to monitor the water level in a smart home.

Malche et al. (2017), presented an IoT-based system for water level monitoring in a smart village in 2017. The main objective of the proposed system is to monitor the water level in real-time from a remote location. The system is divided into three layers: physical layer, service layer, and presentation layer. The physical layer consists of the WSN nodes that detect the water level and the network required to send the recorded values to the service layer. The service layer collects and stores data from the IoT devices using Carriots Platform as a Service (PAAS). The data is displayed using

Freeboard (2023) at the presentation layer. Carriots and Freeboard communicate using the REST API. An Arduino Uno R3 board is used in the system.

III. Method

3.1 Proposed architecture

The system must fulfil the purpose for which the research was made, namely that the gateway can receive data from sensor nodes and forward it to the server. This communication mechanism will be depicted in the system design as can be seen in Fig.1.

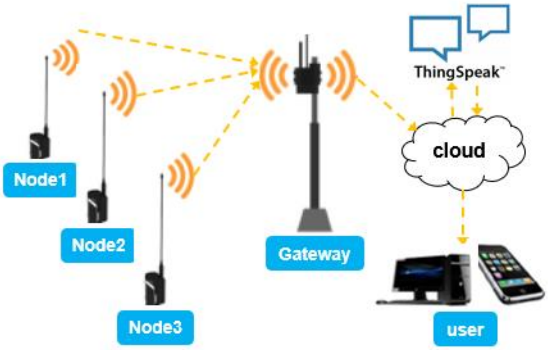
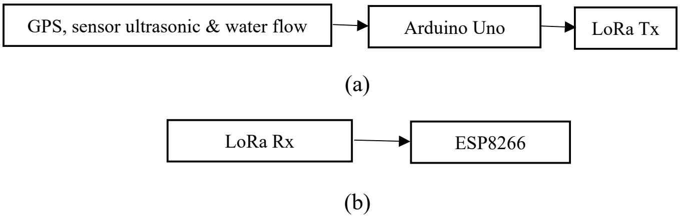


Fig.2. Architecture of system

3.2 Hardware design

In this research, two main units of the system will be designed, namely the node and LoRa gateway. The receiver is the node (Tx) and the transmitter is the gateway (Rx) as shown in Fig.2.



(a)

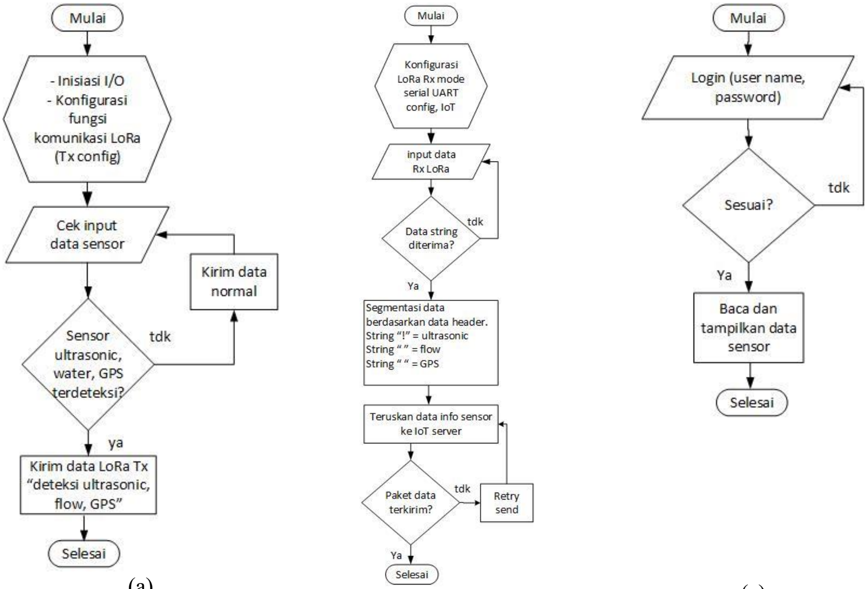
(b)

Fig.2. Device design chart, (a) Node, (b) Gateway

3.3 Software Design on the Node, Gateway, and ThingSpeak Cloud

Designing the workflow of the sensor node is also an important thing that must be done. This is so that the workflow of the system can be known from the sensor node's point of view. For more details on the workflow design of the sensor node can be seen in the flow chart shown in Fig.3(a).

Meanwhile, the software design of how the gateway works has been adapted to the workings of the sensor node to realise the application of gateway discovery supported by both system components. To clarify the workflow of the gateway component on the Arduino nano device can be seen in Fig.3(b) in the form of a flow chart. For ThingSpeak cloud software design according to Fig.3(c).



(a) (b) (c)

Fig.3. Flow chart of software design, (a) node, (b) gateway, (c) ThinkSpeak

3.4 System Testing and Implementation

Testing will be carried out in several stages, namely node testing to find out Tx successfully sent data packets in the form of sensor readings. Then, testing the gateway to find out the data packet is successfully received by Rx. Meanwhile, the system implementation stage will be based on the actual environment. Where for the unit nodes will be placed at several points of the riverbank with each node separated by a certain distance, while the gateway will be placed at the base station. From testing the system implementation stage, data will be obtained in the form of river water levels, river discharge, and RSSI values.

IV. Result and discussion

4.1 Results Hardware design

In general, the system designed in this research has two main devices, namely nodes and gateways. The node device consists of components such as Arduino Uno microcontroller, HC-SR04 sensor, YF-S201 sensor, UBolx Neo-6M GPS, and LoRa-01 (Fig.4a). Meanwhile, the gateway device is an Arduino Uno microcontroller, ESP8266, and LoRa-01 (Fig.4b).

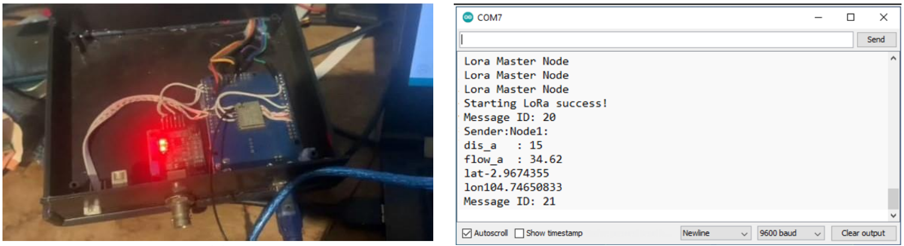
(a) (b)

Fig.4. components in node (a) and gateway devices (b)

The workings of the nodes in the IoT system are as devices that can perform data measurements on the specified measuring parameters. The measurement data is collected and then sent to the gateway device for further processing. Meanwhile, the gateway device in the IoT system acts as a device that can receive and collect data from node devices, and send the data to the cloud server. The communication that occurs between the two devices is facilitated by a communication technique in the form of LoRa.

4.2 Node and gateway device test results

From Fig.5, we can see that the node successfully read the sensors of a number of physical changes and successfully sent the data. The data sent are water surface height (dis_a) of 15, water discharge (flow_a) of 34.62, and GPS data in the form of latitude -2.9674355 and longitude 104.74650833, respectively. This process will take place in real time every time the node detects a change in sensor data.

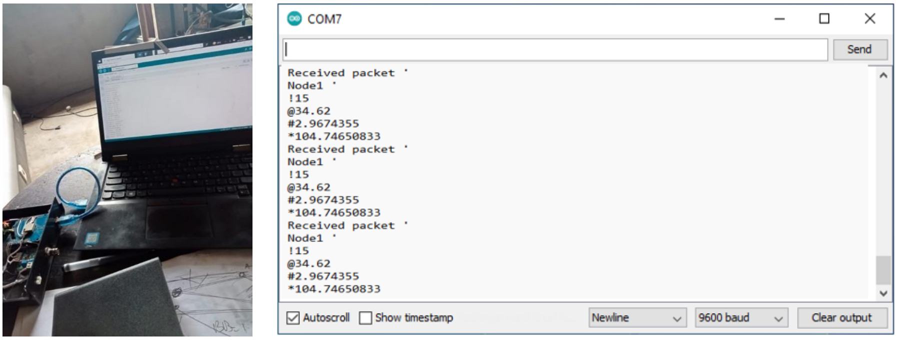


```
Lora Master Node
Lora Master Node
Lora Master Node
Starting LoRa success!
Message ID: 20
Sender:Node1:
dis_a    : 15
flow_a  : 34.62
lat-2.9674355
lon104.74650833
Message ID: 21
```

(a) (b)

Fig.5. Hardware testing of nodes (a) and arduino IDE monitor display at the node testing stage (b)

Meanwhile, the Fig.6 shows that the gateway successfully received data packets from the node. The data sent corresponds to the sensor readings on the node in the form of water level (!15), water discharge (#34,62), and GPS data in the form of latitude @2,9674355 and longitude *104,74650833, respectively. This process will take place in real time every time the node sends data to the gateway.



```
Received packet '
Node1 '
!15
@34.62
#2.9674355
*104.74650833
Received packet '
Node1 '
!15
@34.62
#2.9674355
*104.74650833
Received packet '
Node1 '
!15
@34.62
#2.9674355
*104.74650833
```

(a) (b)

Fig.6. Hardware testing of the gateway (a) and Arduino IDE Display monitor on the gateway (b)

4.3 Implementation Results of Water Level and River Discharge Monitoring System

4.3.1 Node and gateway placement scenario

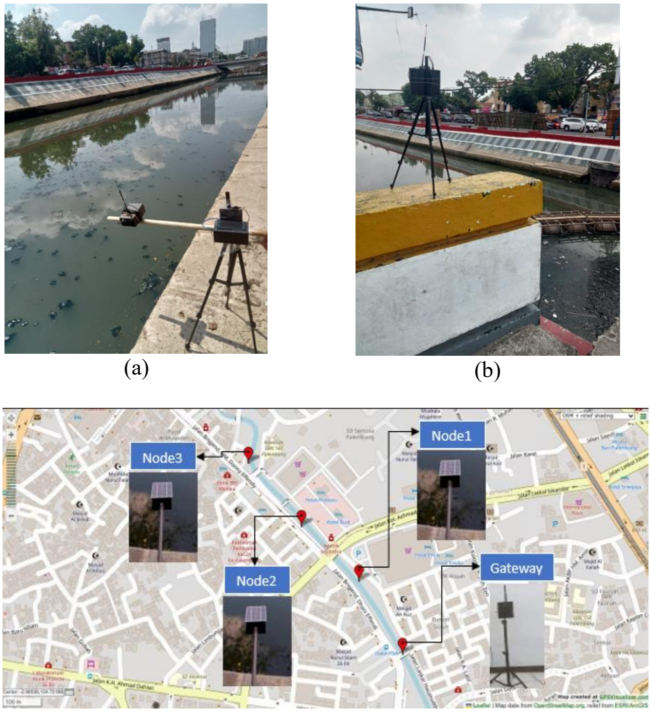
The position of the monitoring system tools in data collection can be seen in Figure 27. The tool is placed on the side of the river for the node (Fig.7a) and in a different place at a certain distance for the gateway precisely on the bridge (Fig.7b). Furthermore, 3 nodes were placed at three different points each 200 metres apart (Fig.7c).

4.3.2 Visualisation of water level and river discharge monitoring system

After the gateway successfully receives data packets from the nodes, the gateway will send the data to the cloud. In this research, the server used is ThingSpeak which has a function as preprocessing, analysing, and visualising data sent by IoT devices (nodes and gateways). In the context of the water level and river discharge monitoring system, ThingSpeak can be used to display data readings from sensors (nodes) in graphical format. The visualisation of the results of monitoring the surface level and water discharge of the Lambidaro river is shown in Fig.8.

4.3.3 Analyse monitoring data of river water level and discharge

The measurement data collection lasted for 3.5 hours at the three points where the nodes were placed. Each node successfully read the physical changes in the water, both the changes in surface height and the flow rate of the river water. From the continuous visualisation on ThingSpeak, we can see an upward trend in the values of both measurement variables. In addition, the pattern of value increase between the two measurement variables is similar. The equation is characterised by when the river water level rises, it will be followed by an increase in river water discharge. The similarity of this pattern is seen in each node, namely node1 (Fig.9), node2 (Fig.10), and node3 (Fig.11). The minimum and maximum values in the measurements of the three nodes are presented in Table 1.



(a) (b)

(c)

Fig.7. Positioning and laying out of research tools

Tabel 1. Average surface elevation and water discharge of Lambidaro river

Node	Water level (cm)		Discharge (m3/s)	
	Min	Max	Min	Max
1	121	124	0,8	1,2
2	121	125	0,8	1,3
3	121	126	0,8	1,4
Everage	121	125	0,8	1,3

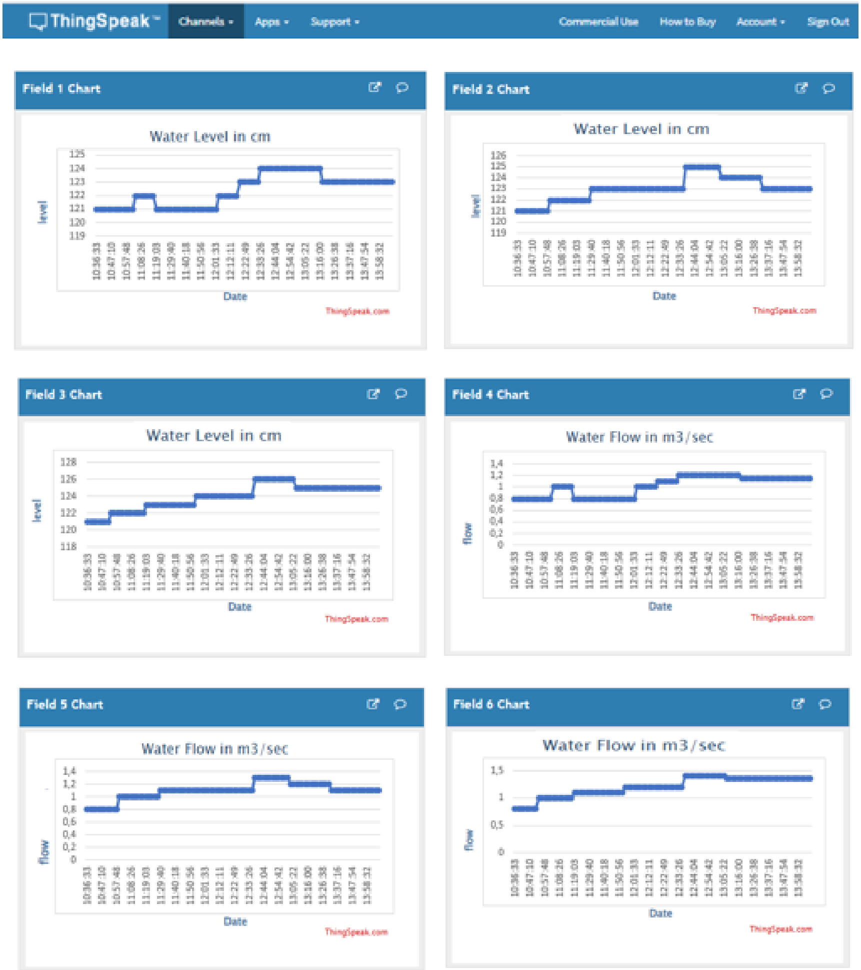


Fig.8. ThingSpeak visualisation: Water level at node1 (Field 1 Chart), Water level at node2 (Field 2 Chart), Water level at node3 (Field 3 Chart), Water discharge at node1 (Field 4 Chart), Water discharge at node2 (Field 5 Chart), and Water discharge at node3 (Field 6 Chart).

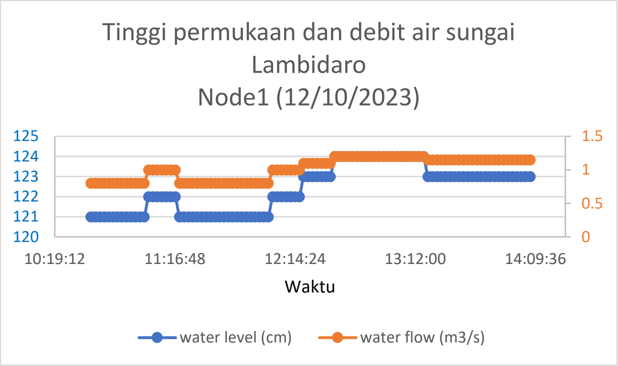


Fig.9. Lambidaro river water level and discharge at node1

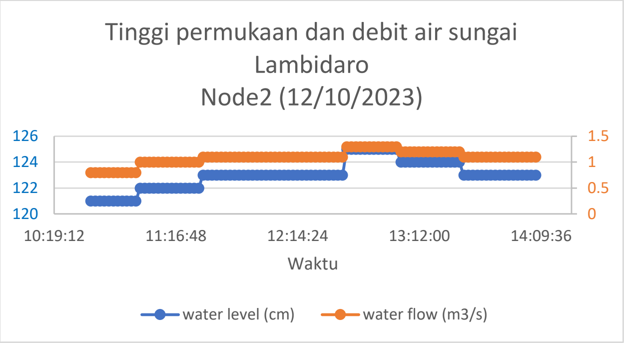


Fig.10. Lambidaro river water level and discharge at node2

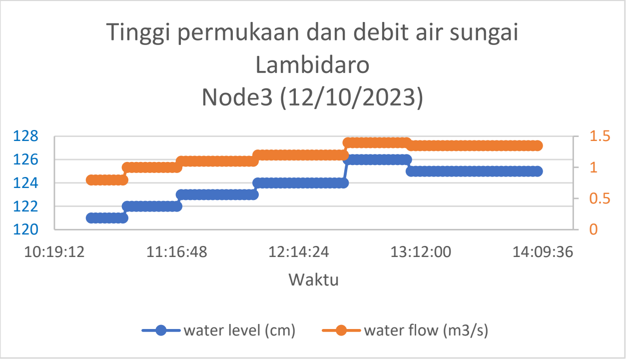


Fig.11. Lambidaro river water level and discharge at node3

4.3.4 RSSI result

In this study, RSSI data was collected. This parameter is intended to determine how strong the signal is between the two tools, namely the node and the gateway. From the experiments that have been carried out, it shows that the signal strength between the three nodes and the gateway has very good and good performance. This indicates that the distance between devices is still within the scope of ideal communication. The RSSI performance is presented in Table 2.

Table 2. RSSI of water level and river discharge monitoring system

Node	RSSI (dBm)	Note
1	-75	Very good
2	-85	Very good
3	-101	good

V. Conclusion

The tool can be made and works at the sensor trial stage. From the three existing sensors, it shows that the sensor has a good level of reponsibility to changes in environmental physical conditions in the form of position or coordinates (UBlox Neo-6M GPS), water volume (YF-S201), and changes in distance (HC-SR04). In the node and gateway testing phase, it shows that the node can collect data packets from sensors and successfully send them to the gateway. In addition, the gateway is able to receive data packets from the node. ThinkSpeak as a server is able to visualise the data packets sent by the gateway. There is a similarity in the pattern of measurement results from the three nodes to changes in surface height and water discharge of the Lambidaro river. The strength of communication between the three nodes and the gateway has a very good category.

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