MiSREd: A Low Cost IoT-Enabled Platform Based on Heterogeneous Wireless Network for Flood Monitoring

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Abstract— **Motivated by an inherent difficulty of foreseeing the exact occurrence of disasters, attempts to rapidly detect and forecast associated information leading towards and in the aftermath of the disaster events can help minimize casualties and collateral damage, particularly in the rural and crowded urban environment. An emerging Internet of Things (IoT) technology is considered promising for these purposes due to Its inherent capability of capturing, sending and processing various types of environmental field data in real-time over a large geographical area. In this paper, the authors introduced MiSREd (Multi-input, Scalable, Reliable, and Easy-to-deploy) as the authors' new low cost IoT platform envisioned to meet the needs of an integrated disaster management system. A key part of the MiSREd platform is the incorporation of heterogeneous wireless networks for improvement reliability and availability of message telemetry. Moreover, deployment of low-overhead protocols can improve the network traffic with a lower bandwidth load as a result of data reduction applied to the MQTT protocol. In order to evaluate the effectiveness of MiSREd, an IoT testbed was developed and evaluation was conducted at Western Flood Canal in Semarang, Indonesia. Data transmission testing in the backhaul using the MQTT protocol showed achievement of a transmission delay <150 ms, packet loss < 2%, jitter was around 50 ms, which belongs to the categories of excellent and good, respectively, conforming to the European Telecommunications Standards Institute (ETSI). The use of the MQTT protocol has a positive impact on the quality of data telemetry in the backhaul side.**

Keywords— **Disaster; LoRa; IoT; MiSREd; MQTT.**

I. Introduction

In fact, the cause of natural hazard can be monitored in order to help mitigating the damage, for instance, monitoring the cause of meteorological disaster e.g., heavy rain (flood). To monitor this natural parameter, it is needed to utilize an integrated technology which functions to remotely observe the rain and river's water level. IoT comes as the solution [1].

The IoT system as the solution for remote potential flood monitoring in the river [2], [3]. This research carried out to make an IoT water level detector prototype. The water level was monitored by employing a water level sensor. Once the water reaches the sensor above the specified safe level, the notification shall be transmitted through cellular network using Short Message Service. In contrast, in the system proposed by Hanan, *et.al* [4] and Varma, *et.al* [5], water flow

and ultrasonic sensor became the main materials to make IoT-based flood early warning system. The sensor functioned for measuring the water level. By using ESP8266, sensor data was acquired and processed, then distributed over a Wi-Fi network. Moreover, It has also been employed in some previous studies [6]–[10] respectively, as well to transmit water level data from the river using 2G/3G cellular networks. Besides, utilizing the Wi-Fi networks, MQTT protocol has been implemented to It as well. MQTT was implemented for unstable cellular networks in rural watershed [9]. Moreover, the IoT framework design with each sensor nodes straightforwardly associated to the server by using data balance (cellular network) may cause a waste of resources in the event these are deployed over a wide field. Furthermore, the consumption of energy in the sensor node will become more inefficient, in case the bandwidth and data rate utilized is additionally set at a better run [11].

Reference	[2], [3]	[4]	[5]	[6]–[10]	[12]	[13]	[14]	[15]	**This Work**
WSN Transmission Technology	GSM	WLAN	WLAN	-	LoRa	LoRa	LoRA	LoRa	LoRa
Protocol Communication for Internet	-	HTTP	HTTP	HTTP /MQTT	Not specified	MQTT	Not specified	HTTP	MQTT
Backhaul Network Technology	-	WLAN	WLAN	GPRS /WCDMA	Not specified	WLAN	Ethernet/LTE	GPRS	WLAN/LTE
Processing Board	Arduino	ESP8266	ESP8266	Raspberry-Pi, Arduino	Arduino	Arduino	Own Dev Board	ESP32	Own Dev Board

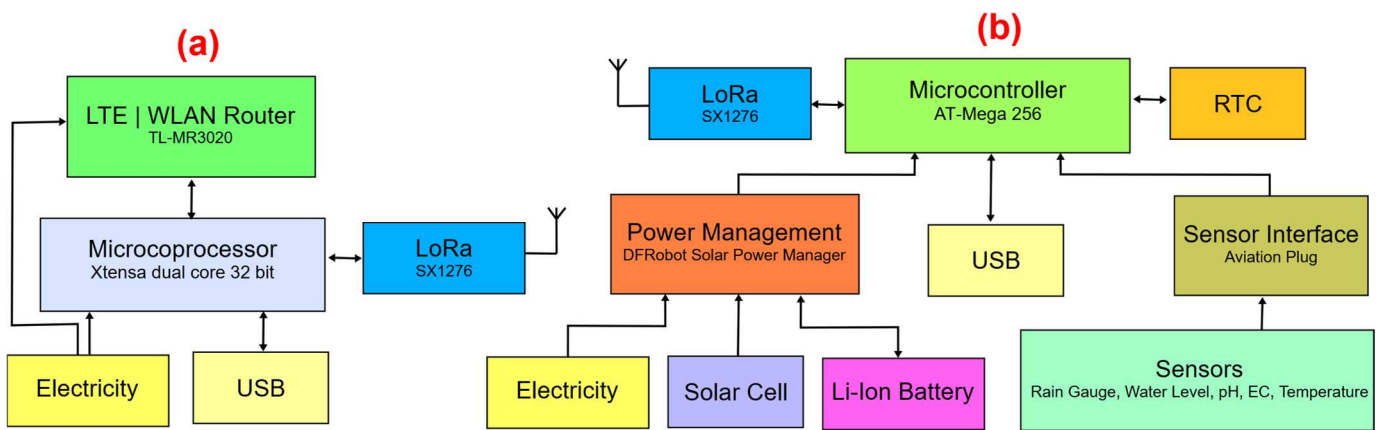| Categories	Excellent	Good	Fair	Bad
Delay	< 150 ms	150-300 ms	300-450 ms	>450 ms
Jitter	0 ms	1-75 ms	76-125 ms	>225 ms
Packet Loss	0-2%	3-14%	15-24%	>25%

Fig. 1 MiSREd's block diagrams of (a) gateway and (b) sensor node.

To overcome the matter about the efficiency of energy used and costs of the data and also improve the reliability of data telemetry, there is a Low Power Wide Area Network (LPWAN) as the solution to address these issues [17]. There are two popular LPWAN technology, Sigfox and LoRa/LoRaWAN [18]. LoRa/LoRaWAN to be more popular than Sigfox, because It gives more economist deployment network, where the Sigfox's network coverage is more expensive and less accessible [19]. It can be proven by research that was conducted by Ortega-Gonzalez et.al [12], where some radio technology for wireless sensor network (LoRa, Sigfox and XBee) was evaluated. Based on this research, LoRa was the most suitable wireless sensor network (WSN) in rainfall monitoring system that was developed, in terms of high signal sensitivity, low battery consumption, and low implementation costs. In previous work, Suharjono et.al [13] conducted a research to evaluate accuracy of water level and water quality sensors and also performance of LoRa under multi-hop topology by using an Arduino-based prototype sensing node. In this research, the hardware robustness of sensing node was less good, and the performance of the lora network cannot be maximized, due to Its antenna heigh installation (under 1.5 meter above ground level). Furthermore, Ragnoli et.al [14] was conducted a research to develop an autonomous flood monitoring system using LoRa. This system used own development board and

using wall mounted sensors enclosure to detect water level. By using these sensors, the real-time water level cannot be measured. Moreover, this research using HTTP protocol to transmit the data to the cloud server. HTTP have larger bandwidth, but has a wider bandwidth, but it consumes a lot of energy and has a considerable latency. In other research, Sung et.al [15] have developed flash flood monitoring system using development board ESP32-based to control and collect data from water flow, rain gauge, and tilt sensor. LoRa was applied as wireless sensor network and GPRS network as backhaul. By using only GPRS network as backhaul, the potential packet loss will increase significantly.

To overcome some weaknesses from related works, the authors in this paper present the development of a new IoT network platform that is suitable for a potential disaster monitoring (in this case is flood). The platform is expected to have the following features, i.e., multi-sensor inputs, scalability for a various number of nodes, reliability in any type of environment, and having a compact dimension so that it is easy to deploy. The authors call the new platform MiSREd (Multi-input, Scalable, Reliable, and Easy-to-deploy). In this platform, a low-cost gateway was constructed with have two networks (WLAN and LTE network) for redundant, if one of them have a problem. The comparative related works can be seen in Table 1. In this paper, the authors propose a platform design, evaluated the performance of

LoRa network, and discuss a comparative study on performance evaluation (delay, packet loss, throughput and jitter) for QoS 0 and QoS 1 within the MQTT protocol in backhaul. Thus, it is such an important thing for having an awareness about natural hazard potential in every region.
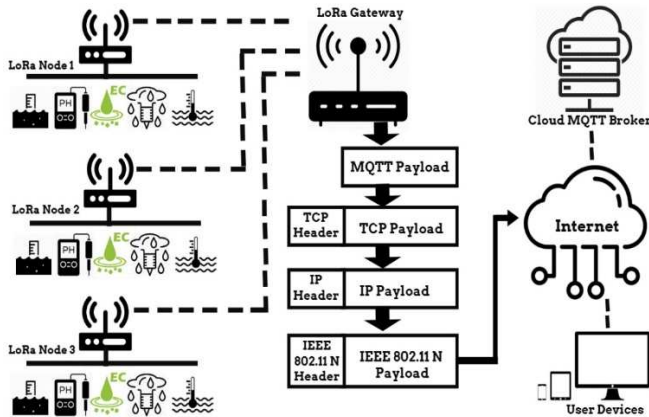

Fig. 2 HetNet architectures.

Fig. 3 Network test location in Western Flood Canal, Semarang. Picture was obtained and edited from Google Earth.

II. Material and Method

A. Proposed Platform

The proposed platform (MiSRed) in this paper consists of two parts, namely (1) hardware, and (2) network. The hardware in this prototype is divided into two parts, namely the sensor nodes and LoRa Gateway. The sensor node consists of AT-Mega256, LoRa radio transceiver (SX1276), temperature sensors, pH sensors, ultrasonic sensors, electrical conductivity (EC) sensors and rain gauge sensors. Where the LoRa Gateway consists of ARM-based microprocessor (ESP32) and LoRa radio transceiver that are connected to the wireless router (WLAN / IEEE 802.11 Network) and LTE Modem. The block diagram can be seen in Fig. 1.

The network aspect in this paper is focused on developing a multi-protocol heterogeneous IoT network using the MQTT protocol. It can be seen in Fig. 2. The heterogeneous wireless network makes use of IEEE 802.11 (WLAN) / LTE cellular network and LoRa standards, in which the WLAN/LTE cellular network is used as a backhaul network to connect LoRa, as a WSN, to the internet.

Algorithm 1 : Flow Process of Gateway Program
   Data : pH, EC, Water Level, Rain Gauge, Temperature
  Do serial communication
  Do connecting to WLAN
  If connecting to WLAN = OK
  | **Then** init LoRa
  Else
        Then do connecting to LTE
        If connecting to LTE = OK
        | **Then** init LoRa
        Else
            Return to serial communication
  Do init LoRa
  If init LoRa = OK
  | **Then** set frequency, TX power and spreading factor
  Else
        Then back to init LoRa
  If there are incoming LoRa Frame
  | **Then** parsing the sensor value to the each variable
  | **Then** Encapsulated the frame to MQTT packet
  Else
        Then wait the incoming data
  Do send MQTT packet to the broker
  Return to wait the incoming data

LoRa is developed by Semtech and intended to be useable in long-lasting battery-powered devices, where energy consumption is absolutely essential. Commonly, LoRa is refer to two separate layers, that are physical layer and MAC layer protocol. In the Physical layer, LoRa using Chirp Spread Spectrum (CSS) and Forward Error Correction (FEC) to modulate signals. LoRa also use Frequency Shift Keying (FSK) modulation techniques in addition to CSS. The adoption of both modulation techniques strengthens the signal against noise and interference in the channel. LoRa includes three critical characteristics to guarantee robustness in modulated signals: Bandwidth (BW), Spreading Factor (SF), and Error Correction Rate / Coding Rate (CR). Furthermore, because SF in LoRa is orthogonal, message (different SF or FSK modulated) that entering the same LoRa channel will not interfere each other. Furthermore, in the MAC Layer, LoRa using LoRaWAN protocol [20].

By using LoRa modulation, the reliability of message exchange under WSN on Physical and MAC Layer can be improved, and the signal to be more robust from interference [21], [22]. Moreover, the effect of using a low data rate on LoRa modulation is less energy consumption with a longer range of radio communication [23], [24]. Meanwhile, using the WLAN/LTE cellular network as a backhaul is based on specifications and performance that is capable of transporting data with a large payload, because it has a larger bandwidth and high data rate. However, this has an impact on considerable energy consumption. To achieve better network availability and reliability, the gateway has been programmed to be able to handover between WLAN or LTE networks, if one of them is having problems.

The heterogeneous wireless network herein is designed to combine WLAN/LTE network with a frequency of LoRa networks is 923 MHz, where both networks are not directly compatible in terms of radio channels, bandwidth, modulation schemes and frame formats. In order to combine them, a gateway device that is designed as a bridge is therefore needed

[25]. The gateway consists of a microprocessor device that is serially connected with the LoRa as a radio transceiver device as well as a LoRa coordinator. It is possible to arrange the gateway module to be able to match the LoRa frame format to the MQTT topic. Messages inside the broker are differentiated and filtered using topics where each message sent to the broker is tagged or bookmarked by the publisher to distinguish each data [26]. The flow of the gateway operation is illustrated in the following Algorithm 1.

Based on Fig. 2, how the proposed platform works. Sensor nodes will read data from water level sensors, temperature sensors, pH sensors, EC sensors, and rain gauge sensors. Then, the data is encapsulated into LoRa frames. Messages that have been encapsulated into LoRa frames, are then transmitted by the LoRa transceiver to the LoRa Gateway. Based on Algorithm 1, once powered on, LoRa Gateway initializes to establish an internet connection with a WLAN. If the WLAN initialization is successful, then the ESP32 will perform the initialization with the LoRa Transceiver. If the WLAN initialization fails, then the ESP32 will perform the initialization with the LTE Module. If the LTE initialization is successful, then EPS32 will perform the initialization with the LoRa Transceiver. If LTE initialization also fails, then the process will be returned to serial communication to repeat initialization with WLAN. Then, the process proceeds to loRa initialization. If the LoRa Transceiver initialization process fails, then the process is returned to loRa initialization. If the LoRa Transceiver is successfully initialized, then the ESP32 will give a command to the LoRa Transceiver to set the frequency to 923 MHz. After that, the LoRa Gateway will turn into frame listening mode. If no frames are logged in, then LoRa Gateway will always listen continuously. If there are frames that enter the LoRa Gateway, then the sensor data in the frame will be parsed and saved to their respective variables, namely pH, EC, Water Level, Rain Gauge, Temperature. Then, the data on those variables will be encapsulated by LoRa Gateway into an MQTT packet with a specific topic. After that, the MQTT packet will be encapsulated into TCP, IP, and WLAN (IEEE 802.11 N) Payload. Then, the packet is sent to the Cloud Server (MQTT Broker + Web + Database Server). The Cloud Server that we built has a Domain Name Server (DNS), which is misrediot.com. Once the data is sent, LoRa Gateway will return to the process of listening for LoRa frames. Data that has been stored in the misrediot.com database will be displayed on the web-based monitoring dashboard.

B. Testing Method

In this paper, the authors employed a test method to calculate the packet data in an actual WLAN/LTE cellular network to analyze the network performance (delay, packet loss, jitter and throughput) based on network loading from accumulated data from a quantity of sensors (15 sensors) and sensor nodes (3 sensor nodes) data sent from the gateway to the MQTT Broker. Each sensor node has 5 types of sensors installed, namely temperature sensors, pH sensors, ultrasonic sensors, EC sensors and rain gauge sensors. In this test, the deployed sensor nodes are 3 pcs. Thus, the total sensor data from the 3 sensor nodes accumulated in the LoRa gateway to be sent to the misrediot.com. Then, the data can be monitored in real time by the user through a dashboard that has been built

on the misrediot.com Web Server. The purpose of sending data to misrediot.com is to ensure that end-to-end data transmission can be carried out, so that the performance of LoRa networks and MQTT protocols can be evaluated and analyzed.

Moreover, the experiments were conducted in the Western Flood Canal at Semarang. The location and sensor nodes deployment plan can be seen in Fig. 3. Meanwhile, the authors used Wireshark to capture packets sent by MQTT on QoS levels 0 and 1 through the LTE public cellular network. The authors adopted a method of measuring network performance carried out by Lee, *et.al* [27]. Moreover, the authors also evaluate packet loss of LoRa network.

The authors analyze the packet loss and delay by capturing packets between the gateway and MQTT Broker for five minutes. The delay is calculated based on the average round-trip delay time / round-trip time (RTT) in TCP between the gateway and MQTT Broker. According to [28], the round-trip delay time can be estimated using formula (1), i.e.,

$$
\begin{aligned}
RTT_n &= (\alpha \; x \; Old\_RTT) \\
&+ \big((1-\alpha)xNew\_Round\_Trip\_Sample\big)
\end{aligned} \quad (1)
$$

where α is constant weighting factor ($0 \leq \alpha \leq 1$). When using Jocobson algorithm the value of α is 0.875. Old_RTT is the time of sending the previous data packet $(n-1)$ and $New\_Round\_Trip\_Sample$ is the time difference between sending data packets to receiving an acknowledgment signal [28], [29].

Furthermore, the packet loss is calculated based on packet retransmission during the testing process within 5 minutes in each section. The authors used three test iterations for data validation purposes. During this experiment, the jitter and throughput are measured using formula (2) and (3), respectively [30], [31].

$$
Jitter = \frac{\sum dv}{\sum Rp - 1} \quad (2)
$$

$$
Throughput = \frac{\sum Rp}{t} \quad (3)
$$

Jitter is a variation of the delta or difference between the first delay and the subsequent delay on the series of packets sent to the server. Based on the formula (2), *dv* is a variation of delay, and *Rp* is the package received [30].

Meanwhile, throughput is the actual bandwidth measured by a specific unit of time used to perform data transfers of a certain size. Based on formula (3) *Rp* is the package received, while *t* is the observation time [31].

III. RESULT AND DISCUSSION

A. Wireless Sensor Network Observation

Before deploying MiSREd at the experiment site, the authors had made observations to determine the quality of available cellular networks. After that, it became known that in such locations, the quality of the available mobile networks was less good. The results of observations and measurements showed that the percentage of packet loss in the area reached 5.48%. Although the value indicates a good category, for the case of disaster risk monitoring, the packet loss value should

be minimized [32]. After conducting several literature studies, the authors decided to choose LoRa for WSN.

In this paper, the helical antennas of the sensor nodes were vertically installed (vertical polarization) at a height of 1 meter and 2 m above ground level (AGL) or 3 to 7 m above sea level, and the Gateway antenna is fixed at an altitude of 2 m AGL or 12 m above sea level. Each sensor nodes were set to transmit data once every 10 minutes. In data transmission experiments with an antenna height of 1 meters AGL, the average packet loss value was 2.06%. Meanwhile, when the sensor nodes were installed at a height of 2 meters AGL, the average packet loss value was 0.52%. Based on the results of these experiments, the height of the antenna installation greatly affects the packet loss value.

Ideally, radio frequency waves would propagate directly along the Line of Sight (LOS), without any obstruction in the first Fresnel zone. However, that is impossible in most real-world scenarios. In the case of real-world environments, often radio frequency waves are distorted due to the phenomenon of reflection caused by obstacles or the installation of antennas at inappropriate heights. To keep the first Fresnel zone from being destructed, the radius needs to be calculated first [33]. Based on such calculations, the minimum height of the antenna can be determined. Fig. 4 provides an illustration of the first Fresnel zone. d is the distance between the transmitter and receiver (Km), while F_1 is the radius of the Fresnel zone (m).

If d is the transmission distance (Km) and f is the carrier frequency (GHz), then F_1 can be calculated using the formula (4), for 60% the first Fresnel zone is free from obstacles [33]. A recapitulation of the results of the F_1 calculation can be seen in Table 3.

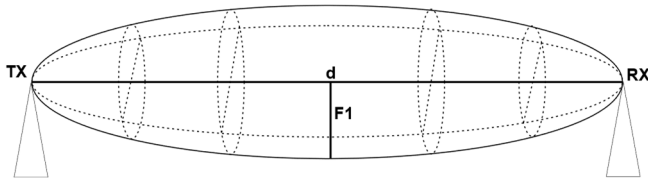$$F_1 = 8.656 \sqrt{\frac{0.6 \, x \, d}{f}} \qquad (4)$$

Fig. 4. First Fresnel zone representation.

TABLE III
RECAPITULATION OF FIRST FRESNEL ZONE RADIUS

d (m)	F_1 (m)	F_1 60% (m)
500	6.37	4.93
1000	9.01	6.98
1500	11.03	8.55

In the real case, the first Fresnel zone can also be obstructed by the curve of the earth. The maximum height of the earth bulge (H) experienced at the midpoint of the link, can be calculated using the formula (5) [33]. However, in this study, the influence can be ignored, because the maximum transmission distance used is 1.5 Km.

$$H = \frac{375d^2}{4R} \qquad (5)$$

where d is the transmission distance (Km), and R is the radius of the Earth (8504 Km).

As previously explained, under real-case scenario conditions, there must be a destruction of the first Fresnel zone. Such destruction will cause phase variations in the reflected signal. If the direct signal and the reflected signal have opposite phases, there will be a weakening of the received signal strength indicator (RSSI). If the RSSI is weaker than the sensitivity of the receiver and noise floor, then most likely the signal will not be able to be demodulated. Then it can cause packet loss, because the receiver has difficulty listening to the signal, due to path loss and destructive reflection phenomena. The minimum tolerance in the clearance of the first Fresnel zone to be maintained is 60% [34].

In this paper, the first Fresnel zone (60%) varies from 4.93 to 8.55 m. That is, the antenna height installation on both sides must be above that range of values. Fig. 5 shows a simulated transmission of radio frequency waves, with the height of the Tx and Rx being 2 m AGL at a distance of 1500 m. While Fig. 6 shows the simulation of the transmission of radio frequency waves with the height of Tx and RX being 9 m AGL at a distance of 1500 m, or exceeding F_1 60%.

Based on Fig. 5, when the Tx and Rx antennas are installed at 2 m AGL, the path loss line is obstructed by the contours of the ground at a distance of 1.21 Km. This causes the attenuation value to increase, so the RSSI received by the Gateway is -88.5 dBm. Whereas in Fig. 6, when the antenna is installed at an altitude exceeding the first Fresnel zone, the LOS line becomes unobstructed by the contours of the ground at a distance of 1.21 Km. Significance, the RSSI received by the Gateway increases to -86.4 dBm. This prove that antenna installations that do not match the required minimum height lead to obstruction of the clearance radius of the first Fresnel Zone. Of course, this causes an increase in the path loss, which then causes a weakening at the received signal level on gateway, so there will be a lot of packet loss [33].

B. Results and Evaluation of MQTT Protocol Performance

After conducting some testing and ensuring that the WSN could work properly and show performance as expected, the authors proceeded to evaluate the accuracy of the sensor reading. Testing of each sensor parameter was carried out in 3 iterations. Then, each test on the parameter is calculated its error value in percent (%). After that, the error value in each sensor test is calculated as the average value. The formula for calculating the error and the average error of measurement of the sensor can be seen in the formulas (6) and (7), respectively [35].

$$\text{Error (\%)} = \left(\frac{Mv - Ev}{Ev}\right) x100 \qquad (6)$$

$$\text{Average Error (\%)} = \frac{Error}{Ns} \qquad (7)$$

Based on formula (4), Mv is the measurement value of the sensor, Ev is the actual value measured by the calibrated sensor. In formula (5), Ns is the number of sensor measurement data samples.
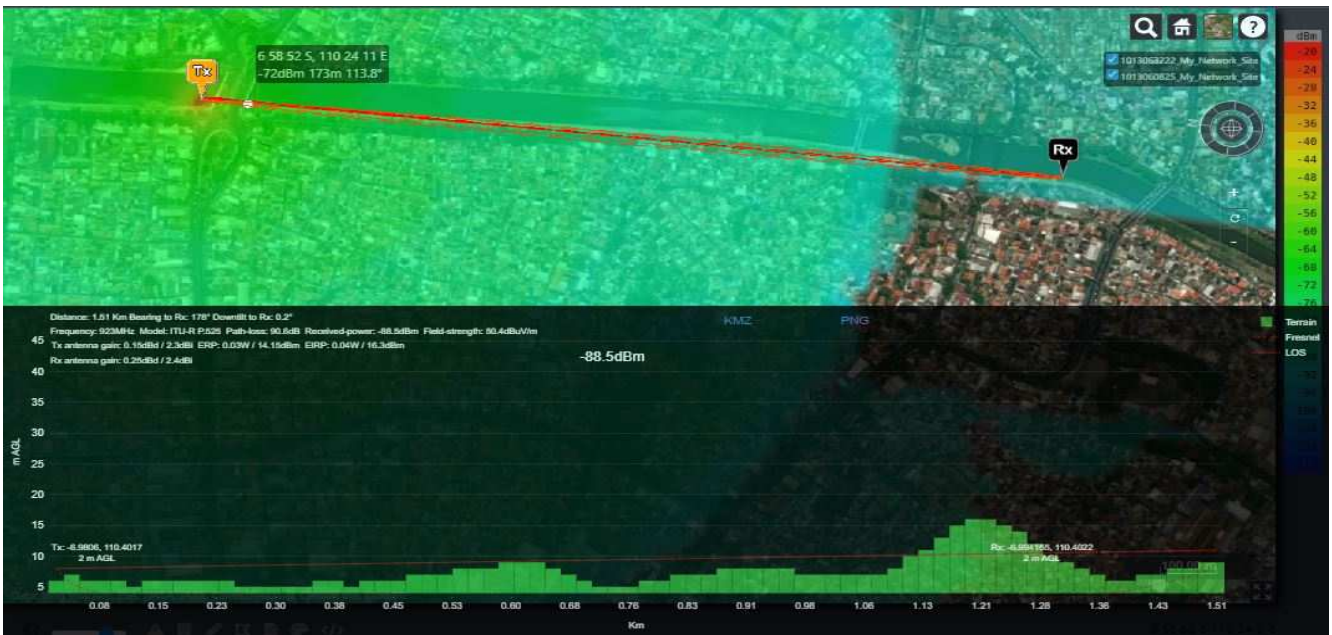
Fig. 5 Transmission simulation of Sensor Nodes and Gateways at a distance of 1.5 Km with an antenna height of 2 m AGL. Picture was obtained from www.cloudrf.com
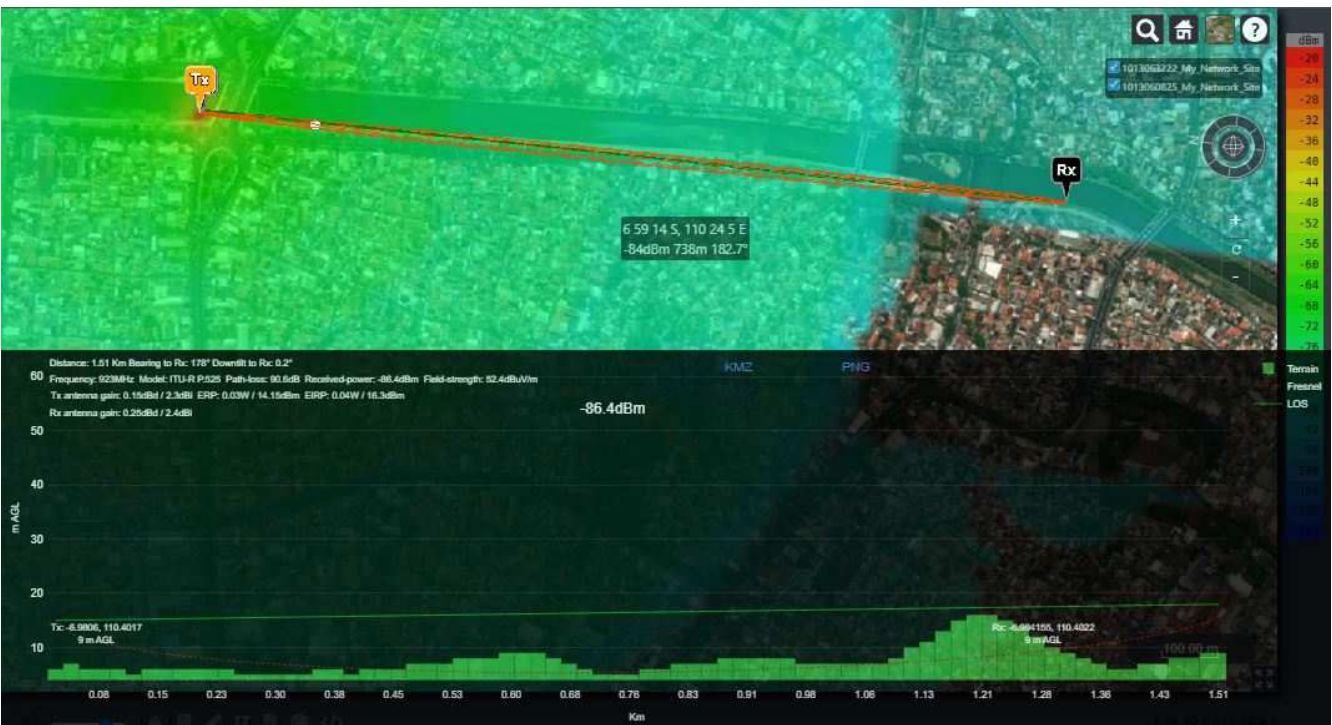

Fig. 6 Transmission simulation of Sensor Nodes and Gateways at a distance of 1.5 Km with an antenna height of 9 m AGL. Picture was obtained from www.cloudrf.com.
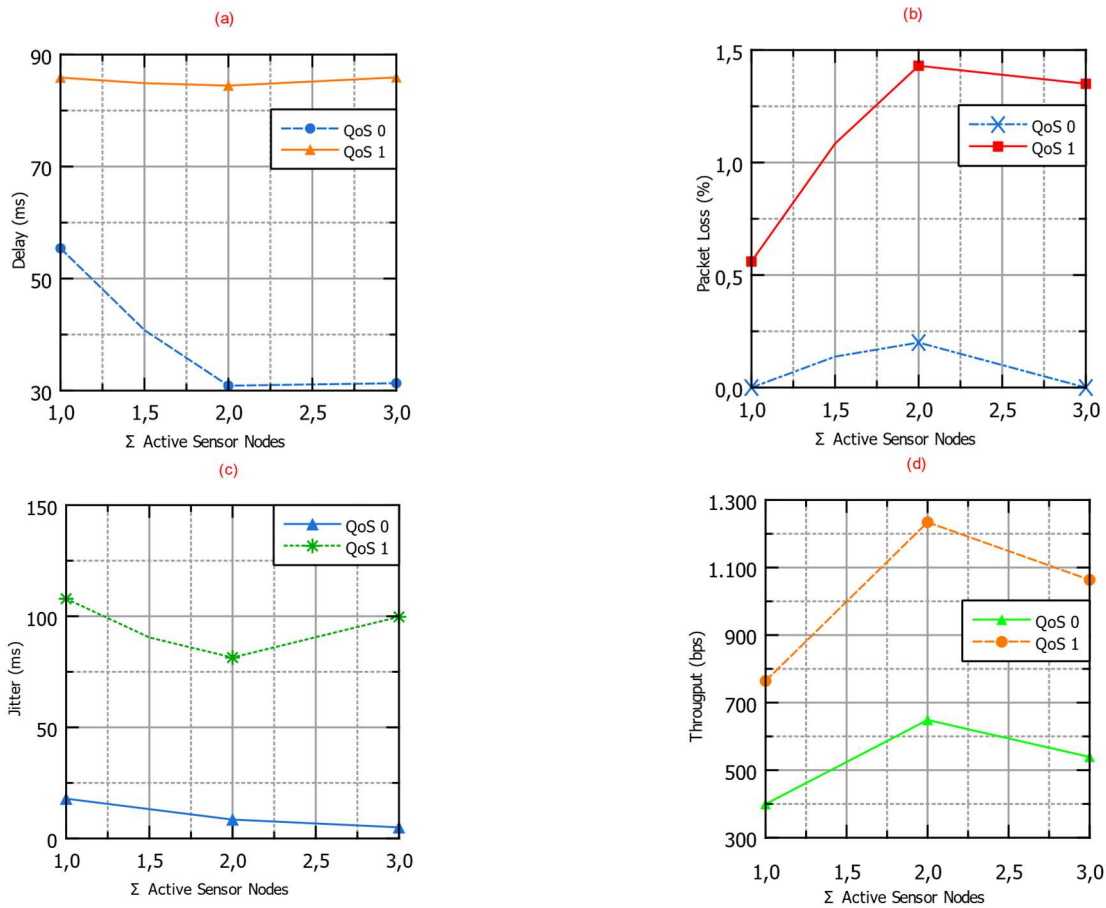
Fig. 7 Performance comparison between QoS 0 and QoS 1 of (a) delay, (b) packet loss, (c) jitter, and (d) throughput.
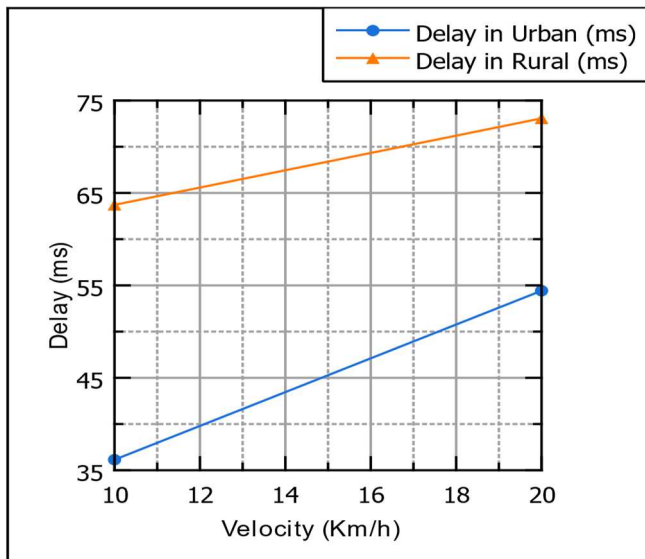

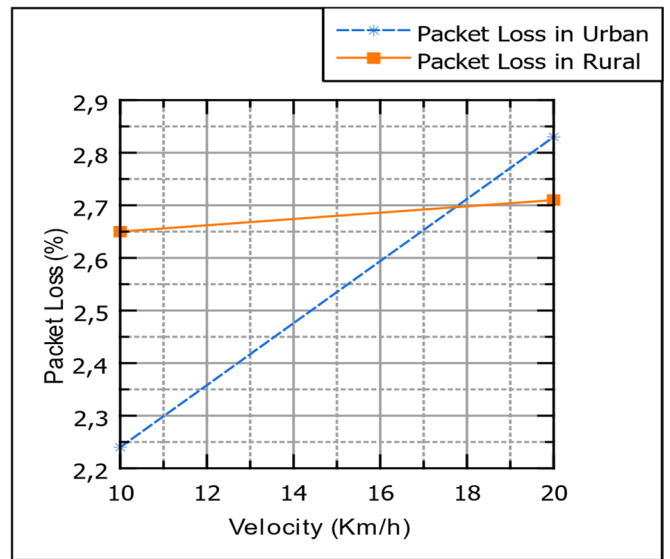Fig. 8 Delay comparison under mobility effect on LoRa .

Fig. 9. Packet loss comparison under mobility effect on LoRa.

TABLE IV
ULTRASONIC SENSOR MEASUREMENT

Ruler (cm)	Sensor (cm)	Error (%)	Average Error (%)
30	30.02	0.07	
40	40.01	0.02	
60	60.02	0.03	0.05
90	90.07	0.08	
130	130.05	0.04	

TABLE V
TEMPERATURE SENSOR MEASUREMENT

Thermometer (ºC)	Sensor (ºC)	Error (%)	Average Error (%)
15	15.05	0.33	
30	30.03	0.10	
45	45.09	0.20	0.15
60	60.04	0.07	
75	75.02	0.03	

Digital pH Meter	Sensor	Error (%)	Average Error (%)
5.04	5.11	1.39	
5.04	5.09	0.99	
5.04	5.08	0.79	0.95
5.03	5.09	1.19	
5.04	5.06	0.40	

Digital EC Meter (mS/cm)	Sensor (cm)	Error (%)	Average Error (%)
12.88	12.9	0.16	
12.88	12.9	0.16	
12.88	12.89	0.08	0.11
12.88	12.89	0.08	
12.88	12.89	0.08	

Based on the test results in author's device, the average inaccuracy measurement of ultrasonic sensor is 0.05 percent. It can be seen in Table 4. Error in measurement may be caused by the influence in unsteady reflected waves within the tube due to the effect of the ripple of water entering the tube, which creates wave reflections not precisely to the echo. Hence, the elapsed time between the transmitted wave and the received wave is slightly greater than the ordinary conditions. Furthermore, 0.15 percent is the average inaccuracy measurement value of the temperature sensor. It can be seen in Table 5. Meanwhile, the average pH sensor's inaccuracy measurement is 0.95 percent, while the average EC sensor's inaccuracy measurement is 0.11 percent. It can be seen in Tabel 6 and Tabel 7, respectively. All sensor accuracy test data showed excellent results because the sensor inaccuracy rate was below 10%.

In other side, the authors in this paper try to prove the performance of the MQTT protocol on the LTE network backhaul, at the time of the network peak load on the backhaul. In addition, the authors also made a comparative study on the QoS levels of the MQTT protocol (QoS 0 and QoS 1) to make a discussion and recommendations for the application of appropriate QoS levels in the backhaul. As mentioned in the section 3, the QoS parameters tested include delay, jitter, packet loss and throughput conforming with ETSI in Table 2.

In the initial evaluation, the authors were conducted delay evaluation using equation (1). When the QoS 0 was applied to the network, the average of delay was 42.58 ms. Where the QoS 1 was applied, the average delay in the network was 85.42 ms. Based on these results, the delay was on excellent category, conforming with ETSI. It can be seen in Table 2. Where the details data can be seen in Fig. 7.a. In this experiment, the QoS 0 has shown better performance than QoS 1. It can happen due to the existence of PUBACK in QoS 1, which rises the delay whenever the broker has received the data [36], [37].

After that, jitter have been evaluated using equation (2). Based on the experiment that had been performed, QoS 0 showed the average jitter value generated was 25.52 ms. Meanwhile, where QoS 1 was applied to the network, the average of jitter was 96.35 ms. Based on the results, QoS 1 has produced a higher jitter value than QoS 0. Jitter and delay have a strong correlation, because jitter is the delay value between packets sent through the network, while delay is the average value of all packets sent through the network. If the delay value is greater, then the jitter value will also increase [38]. This can be seen in Fig. 7.c. In this study, the resulting delay and jitter values were fluctuating against the loading of the network through the sensor nodes. Under ideal conditions,

the greater load amounts on the network, the delay and jitter values will also increase [39]. However, because it was used a sharing public network, so the condition cannot be predicted with certainty [38]. Nonetheless, jitter performance when using QoS 0 represents a good category, according to ETSI. Meanwhile, QoS 1 was in the fair category.

After evaluating the delay and jitter, the performance evaluation is continued to evaluate packet loss. For packet loss evaluation, when QoS 0 was applied, the average packet loss was 0.07%. Where QoS 1 was applied to the network, the average of packet loss was 1.12%. The QoS 1 has a higher average packet loss value, because of the limited broker being only able to receive one data for one second while sending from the gateway to the broker is not given a data transmission interval. This causes congestion in the data queue. In addition, when using the MQTT QoS level 1 protocol, and there is no PUBACK reply, data will be sent back [40]. This process will increase the burden of data transfer [36]. The comparison graph of packet loss values is depicted in Fig. 7.b. Based on the experiment results, both of them on excellent category conforming with ETSI.

The last is throughput evaluation. This value was measured by using equation (3). Based on the result, when QoS 0 was applied to the network, the average of throughput was 529.13 bps. Whereas, when QoS 1 was applied, the average of throughput was 1020.67 bps. In this experiment, the results were also shown fluctuating throughput, because of the unpredicted public network backhaul [38], [41]. The details are depicted in Fig. 7.d.

C. Mobility Effect for LoRa Transmissions

In this section, the authors conducted several additional experiments to determine the effect of LoRa sensor node mobility on WSN performance. In this case, the parameters that the authors want to know and investigate are delay and packet loss. The results of this experiment will later be used by the authors to develop a monitoring device for water level and river water quality with a floating system mechanism design. With this mechanism, the sedimentation process in the river will also can be monitored. This research was conducted in urban and rural areas in the city of Semarang. The research was conducted by sending artificial sensor data that was carried on a motorcycle at a speed of 10-20 km/hour with a maximum distance between the sensor node and the gateway is about 1.5 km.

The experiment began by measuring the delay on the LoRa network, then continued with the calculation of packet loss. The delay is calculated based on the time difference recorded when the message is received by the gateway with the time when the message was delivered by the sensor node. Meanwhile, packet loss is calculated based on the percentage

of the number of packets lost during data transmission. The iteration of the test is carried out three times, then the average result is calculated. Based on data obtained from the test results in urban areas, the average delay of message transmission when the movement speed of the sensor node is 10 km / h, which is 36.14 ms with a packet loss of 2.24%. Meanwhile, when the movement speed of the sensor node is 20 km / h, the average delay of message transmission and packet loss is 54.42 ms and 2.83%. After that, it is continued in the rural area. In this experiment, the authors used the same method as testing in urban areas. results Based on measurements, the average delay and packet loss on the sensor nodes moving at a speed of 10 km/h are 63.71 ms and 2.65%, respectively. When the movement of the sensor node is 20 km / h, the average delay transmission is 73.07 ms and packet loss is 2.71%. Based on ETSI, the average value of delay and packet loss is classified as excellent.

Based on Fig. 8 and Fig. 9, the value of delay and packet loss in rural areas tends to be greater than in urban areas. This is because the channel environment in urban areas tends to be LOS, while the channel environment in rural areas is more hindered by vegetation density and uneven soil contours. This then causes destruction in the first Fresnel Zone, then it affects the level of signal reception data which then makes packet loss increase. In addition, the movement of the sensor node also causes a Doppler effect [42], then it causes a shift in the carrier frequency (Doppler Shift). In this study, the influence of Doppler Shift has not shown a significant effect on the quality of signal transmission in LoRa.

IV. CONCLUSION

Based on all of the experiments, the authors have described MiSREd as the new IoT-Enabled Platform for critical situations and disasters risk. Moreover, the authors also have attempted to investigate and evaluate the LoRa and MQTT protocol performance for the platform. It has been shown that the performance of the heterogeneous wireless network and sensor accuracy on the prototype of the early flood detection and river water quality monitoring system was good. From this study, the authors give the conclusion that the use of the MQTT protocol has a positive impact on the quality of data telemetry (delay, packet loss, jitter, throughput) in the backhaul side. QoS 0 was more suitable for transmitting data to the internet using the MQTT protocol. Furthermore, using LoRa for WSN makes node sensor device management easier and the reliability of data telemetry can also be improved.

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