Error Detection Analysis in LoRa Communication in Wireless Sensor Network Implementation with Microcontroller-Based Cyclic Redundancy Check Method

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***Abstract— Wireless sensor networks* (WSN) play a vital role in collecting distributed data for various applications, including environmental monitoring and smart city systems. Although WSNs promise great potential, communication challenges are a major obstacle that can hinder the reliability and accuracy of transmitted data. A study published in 2018 by Smith et al. in IEEE Transactions on Wireless Communications highlighted that WSN communications are prone to electromagnetic interference, channel noise, and interference, which can lead to transmission errors and signal degradation. These problems can be overcome by using error detection methods, one of which is the Cyclic Redundancy Check (CRC) method. This study focuses on analysis using the CRC method which works by adding redundant bits to the data to be transmitted. At the receiver, a division polynomial is used to verify data integrity. CRC will be implemented with 3 Arduino UNO R3 microcontrollers acting as senders and receivers. The input entered in this communication is photo information. Testing is carried out with a communication distance between LoRa of around 0 to 100 meters in open environmental conditions. Next, the sending node and receiving node will exchange information data, the exchange of information will be carried out alternately between node 1 and node 2. The CRC method detects data transmission errors in the form of damage to digital images, damage to digital images is image noise. Image noise causes the received image to be imperfect or damaged such as blurry to changes in color from the previous image. This is because the pixels of the damaged image experience varying bit changes, resulting in colors that do not match the damaged image. The results of the MSE value obtained in this study with the smallest value are189.5476437 and the largest is 210.0797583.**

Keywords— Cyclic Redundancy Check (CRC), Error Detection, LoRa Communication, Microcontroller, Wireless Sensor Network (WSN).

I. INTRODUCTION

Wireless sensor networks (WSN) have become an integral element in a variety of applications, from environmental monitoring to smart city systems. WSNs themselves utilize small, widely distributed sensors that communicate wirenjlessly with each other to collect information in real time [1]. Despite their great potential, WSNs often face communication challenges that can affect the reliability and accuracy of the transmitted data.

One of the main problems in WSN communication is transmission errors. The environment in which sensors operate is often filled with channel noise, electromagnetic interference, and interference, which can cause transmission errors and signal degradation [2]. This noise can cause signal distortion and result in transmission errors that can harm the accuracy of the data sent. Errors or distortions in high-speed and long-distance data still often occur, this can harm system efficiency, result in service failures, and cause significant information damage [3]. Some problems that can occur are Bit Errors due to electromagnetic interference to data sent incompletely or data corruption during the transfer process. On the other hand, information accuracy is very important in WSN applications, such as weather monitoring, hazardous environment detection, and industrial automation [4].

The dynamic topology of WSN networks also poses a serious challenge. Sensors in WSNs can move or fail, which can cause changes in the network structure. These changes can result in connectivity disruptions, data loss, and even degrade the quality of service [5]. The limited energy of WSN sensors is another important aspect that complicates the communication problem. Most sensors in WSNs run on limited resources, such as batteries [6]. Transmission errors that trigger data retransmission not only increase power consumption but also reduce the battery life of the sensors [7]. Therefore, error detection becomes critical in WSNs operating in dynamic environments that are vulnerable to interference [8].

Based on these problems, a method is needed to overcome these communication challenges. The Cyclic Redundancy Check (CRC) method has emerged as a reliable solution. CRC

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works by adding redundant bits to the data to be transmitted. At the receiver, a division polynomial is used to verify data integrity [9]. The advantage of CRC lies in its ability to detect various types of errors, including burst errors that are generally difficult to detect by other methods [10]. The fast and accurate detection capabilities of CRC make it a suitable choice to support communication reliability in a dynamic WSN environment. The application of CRC in WSN not only focuses on error detection but also considers the limitations of processing power and sensor capacity [11]. CRC is known to be efficient in resource usage, with relatively low overhead. Therefore, this method is in accordance with the characteristics of power-limited sensors and ensures that energy efficiency remains a priority [12].

Previous research entitled Parity Analysis in LoRa Communication Using the Arduino-Based Even Parity Bits Method, written by Adjie Rizky Prasetyo, et al., at al., (2022), it can be concluded that the experiment to implement communication between LoRa using Arduino did not work optimally, where when sending the results that came out on the output were unclear or error so that when stopping sending, there should be no data entering the Receiver, but the Receiver received data that did not know who sent it [13]. This proves that communication errors can still occur in LoRa communication [14].

Based on this research, the title of Error Detection Analysis in LoRa Communication in the Application of Wireless Sensor Network Communication with the Cyclic Redundancy Check Method Based on Arduino Uno was developed and taken [15]. Error detection analysis in LoRa communication that focuses on the application of WSN is carried out using the CRC (Cyclic Redundancy Check) method, where the CRC method has more advantages and can overcome problems that cannot be overcome by the Even Parity Bits method in previous studies [16]. Among them is that CRC can detect more and more complex errors compared to even parity bits. CRC can be applied to various data lengths without requiring changes to the method. Conversely, even parity bits are only suitable for data of a certain length and require adjustment if the data length changes [17].

II. METHOD

A. Research Design

In carrying out this research, several systematic stages were conducted, as illustrated in the flow diagram shown in Fig. 1. The research began with a literature study or preliminary research by reviewing reference journals related to Wireless Sensor Networks (WSN), communication using LoRa modules, and the application of the Cyclic Redundancy Check (CRC) method for detecting data transmission errors. This was followed by the hardware design stage, which involved designing and developing LoRa communication devices within a microcontroller-based WSN environment. Next, the software design stage was carried out by implementing the CRC error detection method on an ESP32 microcontroller using a laptop to monitor and detect data transmission errors in the LoRa communication system. Afterward, LoRa communication testing was performed to evaluate whether the designed system could operate properly and reliably. Subsequently, error detection system testing using the CRC method was conducted on the WSN-based LoRa communication. The next stage involved data collection and analysis, focusing on experimental results such as LoRa communication range testing. Finally, conclusions were drawn based on the analysis of the testing results.

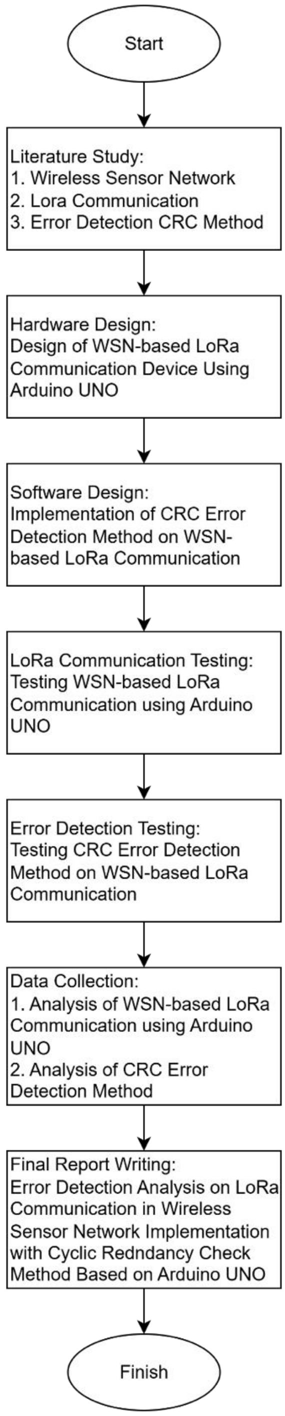

Figure 1. Research Design Flowchart of Error Detection Analysis in LoRa Communication Using CRC Method

1. Literacy study/preliminary research, namely conducting a literacy study from reference journals regarding Wireless sensor networks (WSN), communication using the LoRa module, and regarding the Cyclic Redundancy Check (CRC) method in detecting data transmission errors.
2. Hardware design is the process of making and designing LoRa communication tools in a Microcontroller-based Wireless Sensor Network (WSN).
3. Software design, namely designing a CRC method system applied to ESP32 via a laptop, this is done to detect data errors in the LoRa communication being run.
4. Conducting a LoRa communication test that has been created, by conducting this test it will be possible to determine whether the communication system is appropriate and can be run.
5. Conducting error detection system testing using the CRC method on WSN-based LoRa communications.
6. Data collection/data analysis is the process of collecting data from the results of experiments that have been carried out, namely the results of testing the range of LoRa communication.
7. Drawing conclusions from the results obtained from the test analysis [13].

B. System Design

The system design is depicted in the block diagram below, as shown in Fig. 2.

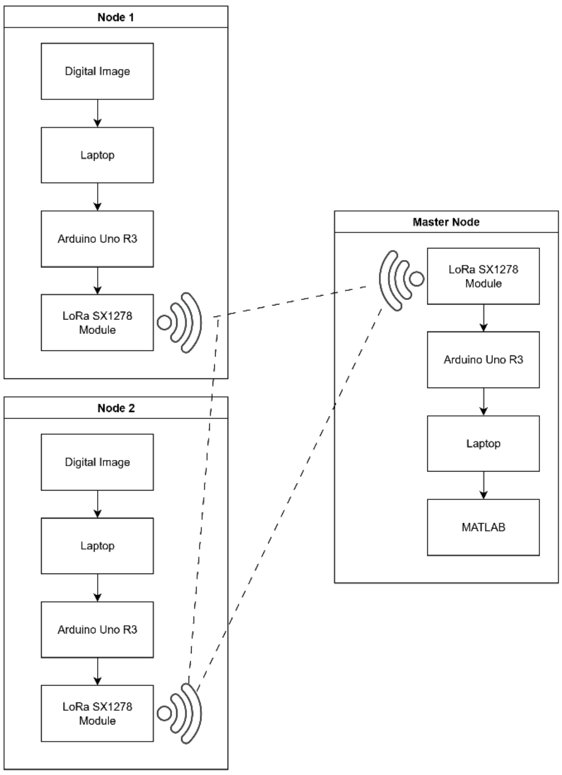

Figure 2. System Block Diagram of WSN-based LoRa Communication

C. System Software Design

Software design is a stage of the system creation flow in the software section. Software design here is the design of the CRC or Cyclic Redundancy Check system method to detect errors in LoRa communication, as shown in Fig. 3.

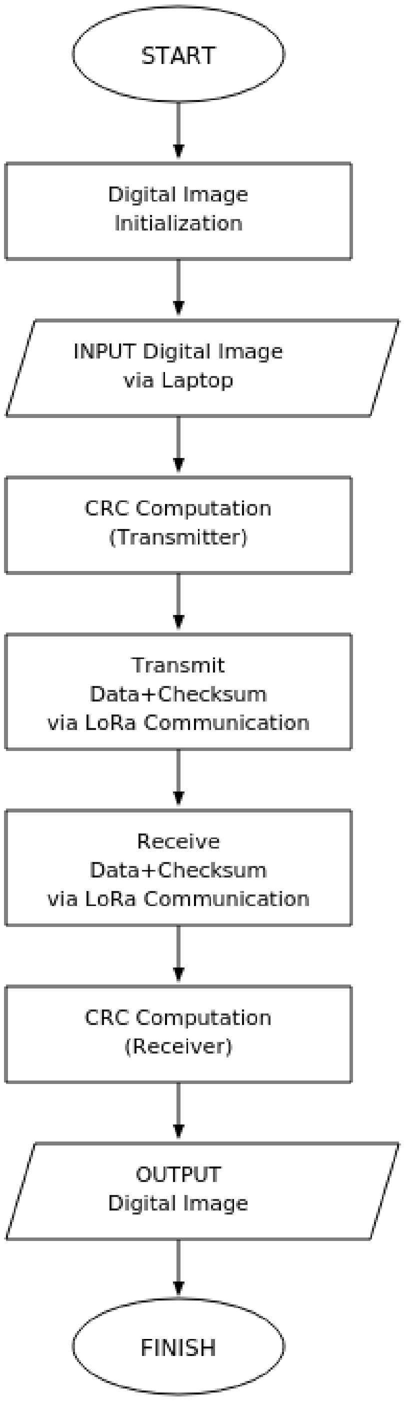

Figure 3. Software Design Flowchart of CRC Error Detection Method in LoRa Communication

D. Tools and materials

The following are the tools and materials used in this research, as shown at Table 1 and 2.

TABLE I

TOOLS AND FUNCTION

No	Tool	Amount	Function
1	Laptop	2	As an interface in testing WSN-based LoRa communication and CRC method error detection in LoRA communication.
2	Arduino IDE	3	As a tool for designing programs and uploading WSN-based LoRa communication programs and CRC method error detection on the ESP32 microcontroller.
3.	MATLAB	1	As a medium for analyzing image pixel MSE

TABLE II

MATERIAL AND FUNCTION

No	Material	Amount	Function
1	LoRa SX1278	3	As a communication medium in the implementation of WSN-based LoRa communication
2	ESP32	3	As processing in detecting errors with the CRC method
3	ESP32CAM	2	As image input (digital image)

E. Testing Parameters

1. LoRa SX1278 Communication Range The distance used as a testing parameter is a range of 10 to 100 meters in open environmental conditions.
2. Testing is done by analyzing bit changes in image data pixels when an error occurs which will be displayed in MATLAB.

III. RESULTS AND DISCUSSION

Testing was carried out at a distance range of 0 to 100 meters, in its implementation the system can work at a maximum distance of 60 meters but the resulting image cannot be opened. So that the distance is taken below 60 meters, namely 50 meters and 40 meters. The following are the test results based on this distance.

A. Distance 50 meters With TX1

The resulting image is displayed in the following data, the comparison between the original image and the disturbed image produces the MSE value.196.2148562, with the total pixel size of the image being 600x800, as shown in Fig. 4.

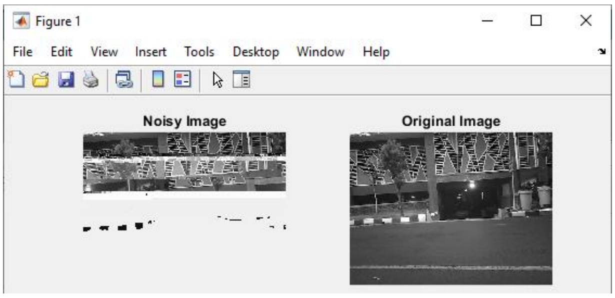

Figure 4. Image Transmission Result at 50m Distance (TX1)

B. Distance 50 meters With TX2

Experiments at a distance of 50 meters using TX2 experienced communication disruption so that the digital image sent was damaged. The MSE value in the analysis process using MATLAB obtained a value ofamounting to 200.229322 of the total number of image pixels, namely 600x800, as shown in Fig. 5.

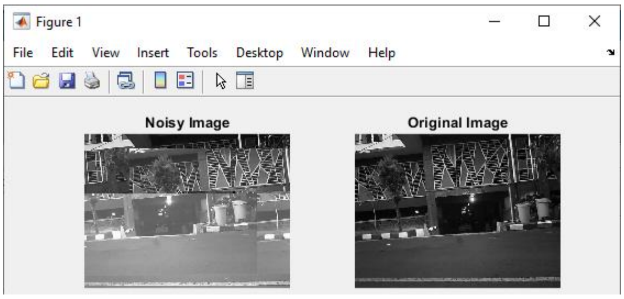

Figure 5. Image Transmission Result at 50m Distance (TX2)

C. 50 Meter Distance With TX1 And TX2

Experiments conducted by simultaneously transmitting between TX1 and TX2 prove that an interference process occurs and the image data cannot be opened or is damaged, this is shown in the Arduino IDE serial monitor in the image below, as shown in Fig. 6

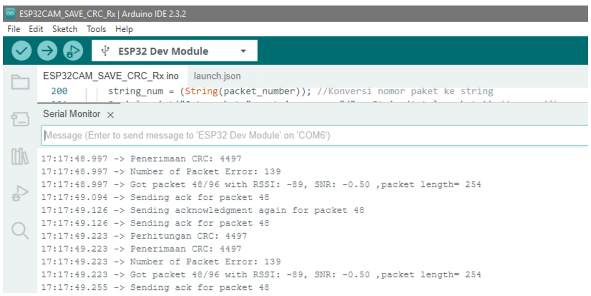

Figure 6. Serial Monitor Output of LoRa Communication

D. Distance 40 Meters With TX1

The calculation of the MSE value obtained in MATLAB with image results at a transmission distance of 40 meters is210.0797583, with a total pixel count of 600x800, as shown in Fig. 7.

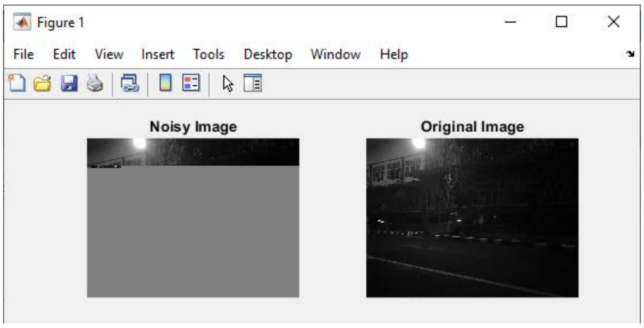

Figure 7. Image Transmission Result at 40m Distance (TX1)

E. 40 Meter Distance With TX2

Experiments with a distance of 40 meters using TX2 resulted in a total of 2 packet errors.And the MSE value obtained is 189.5476437 with the number of pixel sizes of the image being 600x800, as shown in Fig. 8.

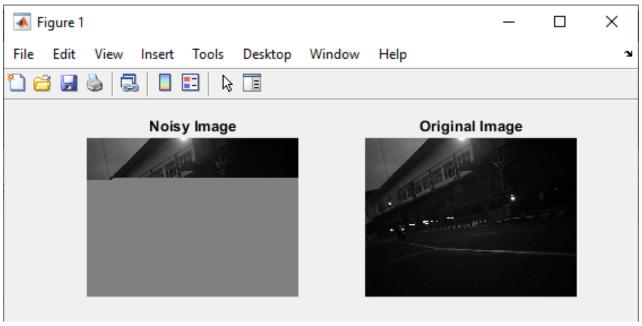

Figure 8. Image Transmission Result at 40m Distance (TX2)

F. 40 Meters Distance With TX! And TX2

Experiments conducted by simultaneously transmitting between TX1 and TX2 proved that an interference process occurred and the image data could not be opened or was damaged.

VI. CONCLUSION

Based on the experiment and research conducted, it can be concluded that the LoRa communication system integrated with the Cyclic Redundancy Check (CRC) method is capable of transmitting and receiving digital image data by dividing the images into multiple packets, with each packet containing 250 bytes. However, the testing results revealed that data transmission at distances of 40 meters and 50 meters experienced interference, resulting in damaged received data, which indicates that transmission errors increase proportionally with distance. Furthermore, simultaneous transmission using two transmitters caused significant interference, rendering the digital images completely damaged and unsuitable for further analysis. The Mean Square Error (MSE) analysis showed values ranging from 189.5476437 to 210.0797583, indicating the degree of image quality degradation due to transmission errors detected by the CRC method.

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