Internet of things and long range-based bridge slope early detection systems

Nuraeni Umar[1,2], Syafruddin Syarif[1], Dewiani[1], Merna Baharuddin[1]
[1]Department of Electrical Engineering, Faculty of Engineering, Hasanuddin University, Gowa, Indonesia
[2]Department of Electrical Engineering, Faculty of Telecommunication, Ujung Pandang State Polytechnic, Makassar, Indonesia

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ABSTRACT

This research proposes an internet of things and long range (LoRa)-based bridge slope status monitoring and warning system that is wireless, low-cost, and user-friendly, with continuous data sent. Bridge inspection officers can easily obtain bridge slope data via a web browser on a cell phone. The design uses Arduino integrated development environment software and an ITGMPU accelerometer sensors, TTGO ESP32, cellphones, successfully identified tilt angle variations from 0.11° to 15.2° were the research's outputs, and and they were continuously transmitted to the bridge inspection officer's mobile phone. Measurements of throughput, quality of service (QoS), and latency characteristics have been made to assess the internet network's performance. The network system performance statistics show an average measured network delay of 1.2 seconds, a throughput of 85 bps, and a QoS of 0%. Consequently, the system performs well and the internet network performance falls into the very good range.

Corresponding Author:

Nuraeni Umar
Department of Electrical Engineering, Faculty of Telecommunication
Ujung Pandang State Polytechnic
St. Kemerdekaan KM. 10 Tamalanrea, Makassar, Indonesia
Email: nuraeni_umar@poliupg.ac.id

1. INTRODUCTION

Bridges play a crucial function in reducing travel distances in land transportation. Indonesia is made up of islands connected by bridges, as well as rivers that need flyovers and bridges. Even though the infrastructure is designed to last for a very long time, damage to bridge structures typically develops at an uncontrollable rate. Excessive variations in a bridge's slope might cause damage to the structure. In order to allow for logical action to be made regarding the bridge, bridge inspection officials constantly visit and evaluate the bridge's condition. The issue is that because bridges are dispersed so far, it takes thousands of kilometers to reach a bridge for monitoring. By overcoming this and creating a bridge slope early detection system, data may be quickly accessed through a mobile device. Through the use of a web browser, the bridge slope early detection system continuously transmits data remotely to the officer's mobile phone. This is important to know since you can calculate the angle change using this tool.

The system makes use of a message queuing (MQTT) computer network or internet network, long range (LoRa) and the internet of things (IoT). Telemetry transport as data transmission to mobile phones with this method, inspection officials can do so quickly and affordably without having to travel to the bridge's location. The performance of the internet network, including throughput, quality of service (QoS), and latency characteristics, is monitored to assess the network's quality. Investigate the creation of a system that combines accelerometer sensors with LoRa and IoT technologies to detect a bridge's slope initially. To monitor vibrations, an accelerometer sensor is mounted on the bridge body [1], and computing the bridge's vertical deflection [2]. The three measurement axes of the MMA7361L accelerometer sensor type are the x, y, and z axes. The aim of this accelerometer is to measure an object's acceleration in gravitational units (g).

Radio is a wireless or wireless communication system. This technology is not limited by cable length. Radio is a simple communication medium with long distance reach, the function of radio media is to spread messages, information, music in all directions over long distances and then be received by radio receivers. Radio transmits with electromagnetic waves, through a modulation process where the information signal is combined with the carrier signal. Radio can be used to store and transmit digital information or data, broadcast radio transmitters only transmit in one direction, the LoRa system itself has a transmitter and receiver. LoRa is a radio system that is frequency modulated, with a frequency band of 433-868 MHz, 915-923 MHz, for the Asian area the frequency used is around 923-925 MHz. LoRa technology uses low power, its range reaches 15 km in remote areas, this technology is good for transmitting small data, namely around 10-20 bytes. The bridge slope change detection system was built using the LoRa radio network.

The bridge tilt detection system was created using an IoT-connected accelerometer sensor. IoT is the internet of everything, an internet network connected to a sensor system, which functions to transmit sensor detection data. IoT is the most advanced technology and its implementation continues to develop in various fields. IoT has a significant impact on every facet of contemporary culture [3], the application of wearable IoT devices is becoming more advanced, increasingly widespread, starting from social networking, payments, and navigation, to health monitoring [4], applying accelerometers with IoT devices to earthquake detection [5], reading sensors and sending data for warnings before a disaster occurs [6]. The slope of the building and physical structure was observed using a data acquisition system utilizing the ADXL335 accelerometer sensor [7]. Accelerometer sensor instrumentation system, signal conditioning, with ATmega 32 microcontroller [8]. To analyze the strength of the bridge using an accelerometer (ADXL345) as a vibration sensor [9]. Accelerometers are devices that are widely used to determine bridge vibrations [10], [11]. Control all nodes via the IEEE 802.11 wireless network, easily and sample deviations, vibrations due to load and water level [12]. The use of a single microelectromechanical systems (MEMS) accelerometer, namely the MMA7361L, for the tilt sensor [13]. Wireless communication and IoT transmission are powerful extensive cognitive processing and highly effective capabilities in the field of bridge inspection [14].

This research will measure the throughput, delay, packet loss parameters, which previous research used the MMA7361L accelerometer sensor is connected to Zigbee 802.15 [15]. Automatic distance and slope measurement system using an IoT-based microcontroller [16], [17]. IoT MEMS accelerometer for translational measurements of motion line actuators and vibrations of Great rotating machines [18]. Accelerometer to detect jerks on the bridge, vibration sensor to detect vibrations that occur on the bridge [19]. IoT technology and sensors in identifying cracks in bridge structures and building a bridge structure health monitoring system [20]. The radio frequency identification (RFID), real time control (RTC) and liquid crystal display (LCD) interfacing modules are connected to the ESP32 microcontroller, and the IoT [21]. Wi-Fi module, ESP8266-12 for connecting to the system internet. The concept of publisher and subscriber is used for communication [22]. IoT using WiFi and MQTT can display blood pressure, blood flow, dialysate temperature, and conductivity of dialysate fluid [23]. LoRa technology is suitable for IoT application scenarios to transmit small amounts of data over long distances and to transmit data with low power consumption [24], [25]. Based on the reference, it is very interesting to realize the accelerometer, LoRa and IoT sensor system by building a LoRa and IoT based bridge tilt detection system.

2. RESEARCH METHOD

The development of an early slope detection system can aid in bridge monitoring and maintenance, preventing further damage and extending the bridge's life. The gadgets are divided into two groups: hardware (which includes an ESP32 microcontroller, an accelerometer sensor, an internet network, a laptop, and a smartphone) and software (which includes the Arduino integrated development environment (IDE) program, windows 10 64-bit). Employees that check bridges utilize a laptop or smartphone with a web browser to access real-time data on bridge slope early detection. The accelerometer sensor sends a digital signal to the ESP32 microprocessor, which interprets changes in the bridge's slope as an angle. The ESP32 has a LoRa transmitter and receiver system that can send signals to an internet system or deliver data to the cloud.

Utilizing an accelerometer, ESP32, LoRa, internet connection, and cellphone, the system was constructed. The internet is a computer network that is connected to each other via the internet protocol package (TCP/IP) so that it is connected throughout the world. IoT systems are devices that connect to the internet, collect data and perform actions or controls. System testing/experiments were carried out in the Microprocessor Laboratory of the Telecommunications Engineering Study Program, Department of Electrical Engineering, Ujung Pandang State Polytechnic. An accelerometer sensor that is integrated with the

LoRa and IoT systems is utilized to detect changes in the inclination angle of the bridge. Figure 1 shows the design of this system. A bridge slope early detection model utilizing LoRa and IoT.

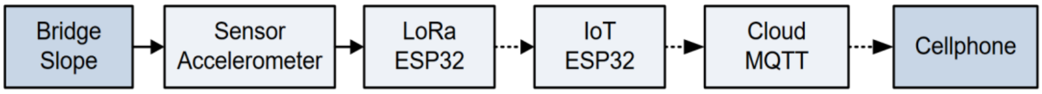

Figure 1. System model for early detection of bridge slope using LoRa and IoT

The bridge tilt detection system uses an accelerometer sensor to read changes in deviation that occur, and data on electrical quantities, namely digital signals entering the ESP32 microprocessor with Lora and IoT cloud received by the smartphone. The accelerometer sensor will detect changes in tilt angle, the data is sent to the ESP32 microprocessor transmitting data via radio communication, namely LoRa which consists of a transmitter and receiver. The transmitter then transmits to the internet network system, received by the cellphone. It is hoped that the system will function to detect changes in the angle of the bridge, be able to transmit data continuously, data will be received via the computer network by the inspection officer's cellphone properly.

An accelerometer is a transducer that is capable of detecting acceleration and measuring vibrations to measure the Earth's gravitational acceleration. This is in accordance with the type and type of accelerometer sensor, namely the MPU 6050 accelerometer sensor with three measurement axes, namely the x-axis, y-axis and z-axis. Message exchange with the publish/subscribe model in MQTT is an alternative to the client-server model, where clients (publishers/subscribers) communicate directly with other endpoints on a topic through brokers whose job is to filter messages and distribute them [23]. IoT technology is a concept where objects can transmit data over a network without human-to-human or human-to-computer interaction. The IoT is most closely related to machine-to-machine (M2M) communications. The ESP32 microcontroller provides a standalone WiFi network solution in the form of a microcontroller bridge to the WiFi network. ESP32 uses a dual-core processor running on Xtensa LX16 [6] instructions.

Building an early detection system for bridge tilt using LoRa and IoT. Research instruments; specifications for device requirements are as follows: laptop, cellphone, accelerometer sensor, ESP32 microcontroller, power supply 5 Volt. Software: windows 10 64-bit operating system using Arduino IDE, MQTT lens. This research uses the ITGMPU accelerometer and the TTGO ESP 32 IoT strap which is equipped with the LoRa system.

Measuring internet network performance, the parameters measured are throughput (bps), delay (seconds), packet loss. The quality of the network sent will be measured for the data sent, to determine the network's ability to provide better services, guaranteeing the level of network performance; throughput parameters are the effective data transfer speed, the total number of packet arrivals during the time interval in bits per second, QoS regulates the quality of data traffic services, overcomes packet loss and network delays. Throughput, QoS, and network delay are transmission process times that depend on the distance from the data origin to the data destination. This system measures on the slope of the bridge and measures that quality from network used. Obtaining network performance is important for determining the quality of internet network services, for identifying performance problems and network efficiency.

Figure 2 shows the steps to build this system. To make it easier to understand the process of this system, it can be seen in Figure 2 which shows an overview of the process flow/steps of the bridge angle tilt detection system. From the first picture, start with the starting steps, the second is the declaration of tilt variables port, solid-state drive (SSD), password, cloud MQTT, the third step is network connection LoRa, the fourth step is the tilt detection process, the fifth step is sending data to the LoRa recipient, the sixth step is giving a 10 second delay , step seventh step receive data from LoRa delivery, eighth step internet network connection, ninth step send data to the cloud, tenth step receive data to the cloud, eleventh step display slope data, twelfth step detect again, end of the thirteenth step program stops. Figure 3 show bridge slope the initial detection system using LoRa and IoT. From Figure 3, this system is simply built using an ITGMPU type accelerometer and ESP32 type TTGO, IoT internet network.

Figure 4 show data from measuring the bridge slope early detection system using LoRa and IoT. Figure 4 shows the bridge tilt angle detection data display on the inspection officer's cellphone. This system measures on the slope of the bridge and measures that quality from network used.

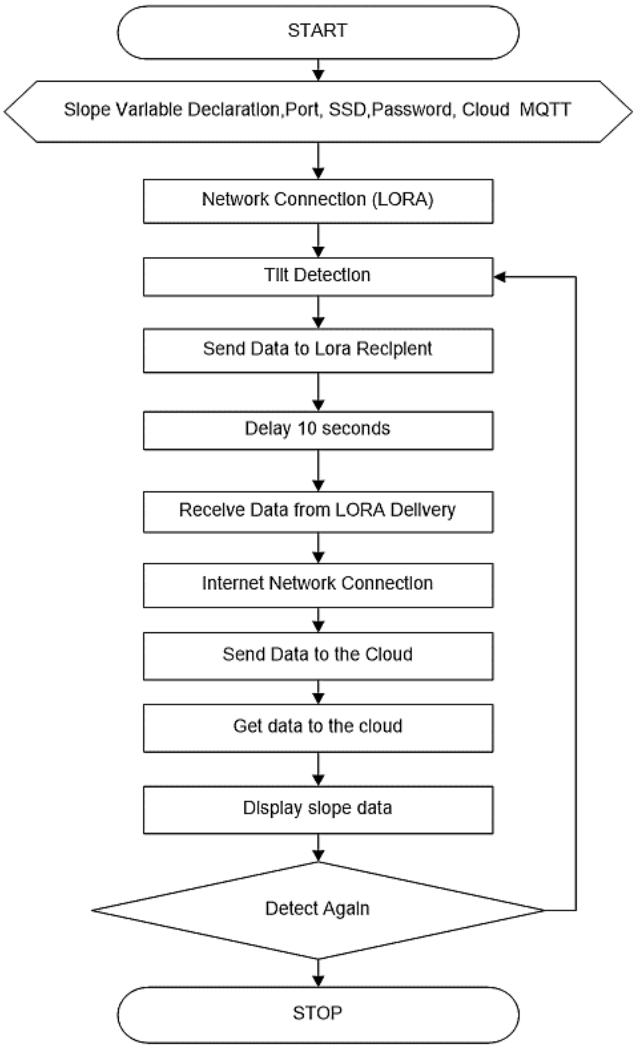

Figure 2. Bridge slope system flow chart for early detection using LoRA and IoT

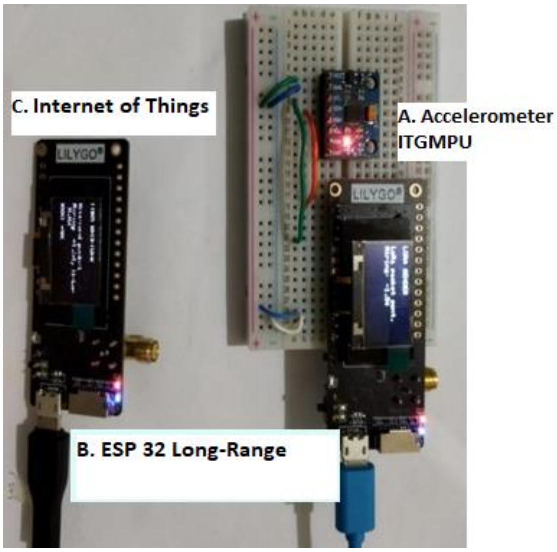

Figure 3. Bridge slope the initial detection system using LoRa and IoT

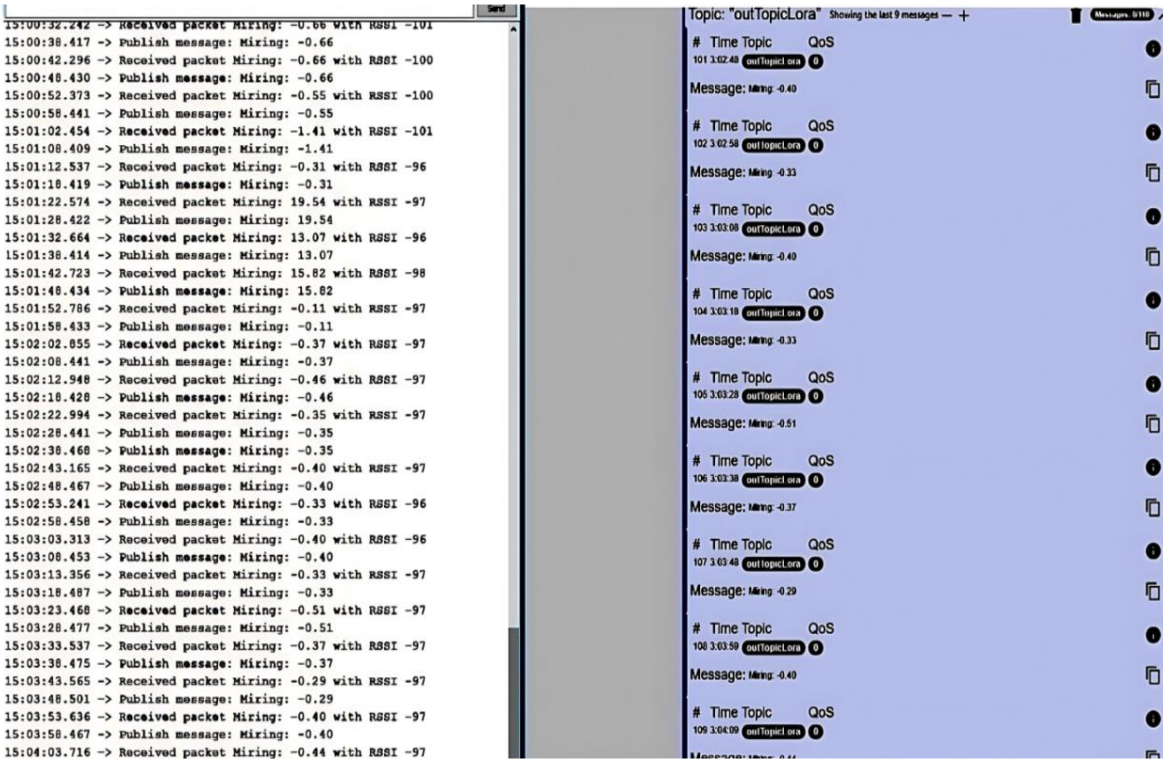

Figure 4. Display data from the slope of the bridge detection system using LoRa and IoT

3. RESULTS AND DISCUSSION

The accelerometer system receives changes in the tilt angle of the bridge, the data will be forwarded to the ESP32 which has a LoRa system, LoRa will send the data to the LoRa receiver and then the LoRa receiver sends it to the IoT internet, which can be viewed using a web browser page on a smartphone. Data from early detection of bridge slope using accelerometer, IoT, LoRa sensors produces early detection of bridge slope of 0.11° to 15.2°. The latest findings involve creating a low-cost tool by utilizing an ESP32 type TTGO microcontroller in conjunction with an accelerometer sensor.

This system measures on the slope of the bridge and measures that quality from network used. To determine the quality of internet network services, delay parameters are measured. Throughput, QoS, for identify network performance and efficiency. This research measures system performance, namely throughput of 85 bps, QoS 0% and delay of around 1.2 seconds. From the results obtained, the performance of the bridge slope early detection system has very good performance based on the standards issued by TIPHON.

Data from measurements from the IoT and LoRa-based early detection system for bridge slopes obtained from the results of early detection of bridge slopes with throughput, QoS, system delay, in Table 1. This system provides benefits, namely the ease of obtaining data on changes in bridge slope quickly, continuously on mobile phones. Measuring throughput parameters, QoS, system delay, to determine the quality of the network used. The bridge angle tilt detection system can be implemented on the bridge. The data are shown in Table 1.

Table 1. Measurement table for the bridge tilt early detection system with IoT and LoRa, as well as throughput, QoS, and delay

Number of test	Accelerometer sensor tilt angle	Throughput	QoS (%)	Delay	Category: throughput, QoS, latency
1	0.11°	89 bps	0	1.12 second	Very good
2	1.41°	85 bps	0	1.23 second	Very good
3	13.7°	85 bps	0	1.24 second	Very good
4	15.2°	81 bps	0	1.34 second	Very good

4. CONCLUSION

Based on the results of the research and discussion, it shows that the system with the ITGMPU accelerometer sensor, TTGO ESP 32, LoRa, IoT, cellphone, the system sends data continuously, accessed using a web browser page. The system functions well. The benefit is that it makes it easier to monitor the slope angle of the bridge on a smartphone. The bridge tilt angle detection system succeeded in identifying tilt angle variations of 0.11° to 15.2°, which is the research output and continues to be sent to the bridge inspection officer's cell phone. The system for measuring internet network performance, the results obtained in this research were throughput of 85 bits per second, QoS of 0% and to measure network delay, an average delay of 1.2 seconds was obtained. The system has internet network performance in the very good category. This research can be developed by providing information on normal or dangerous conditions to bridge users.

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BIOGRAPHIES OF AUTHORS

Nuraeni Umar received her bachelor's degree in electrical engineering from Hasanuddin University, Indonesia, in 1996, a master's of technology in electrical engineering specializing system telecommunication engineering from Institute Technology Bandung, Indonesia, in 2005. She is a lecturer in Department of Electrical Engineering, Telecommunication Faculty, Ujung Pandang State Polytechnic, Makassar, Indonesia, from 1987. Her research interests include telecommunication system. She can be contacted at email: nuraeni_umar@poliupg.ac.id.

Syafruddin Syarif received his B.E. degree in electrical engineering specializing in telecommunication and electronica from Hasanuddin University, Indonesia, in 1986, a master's of technology in electrical engineering specializing system information telecommunication from Institute Technology Bandung, Indonesia, in 1996. Engineering science in University Hasanuddin. He is a lecturer in Department of Electrical Engineering, Engineering Faculty, Hasanuddin University, Indonesia in 2013. He is a professor computer operation system at the Department of Electrical Engineering, Hasanuddin University. He can be contacted at email: syafruddin.s@eng.unhas.ac.id.

Dewiani received the B.S. in telecommunication engineering from Hasanuddin University, Makassar, Indonesia in 1993, M.S. in system information technology from Institute of Technology Bandung (ITB), Bandung, West Java, Indonesia in 2000 and Ph.D. degree in the Department of Electrical Engineering and Computer Science at the Graduate School of Science and Engineering of Ehime University, Japan in 2013. She is working as a member of staff Department of Electrical Engineering, Hasanuddin University, South-Sulawesi, Makassar, Indonesia from 1995. Her research interests include computer and communication networks, wireless communication and optical networks. She is a member of IEEE. She can be contacted at email: dewiani@unhas.ac.id.

Merna Baharuddin received her B.E. degree in electrical engineering specializing in telecommunication from Hasanuddin University, Indonesia, in 1999, received her M.E. degree in telecommunication engineering from Monash University, Australia, in 2002, and Ph.D. degree from Graduate School of Advanced Integration Science, Chiba University, Japan, in 2010. She is a lecturer in Department of Electrical Engineering, Engineering Faculty, Hasanuddin University, Indonesia, from 2005. Her research interests include microstrip antennas, radars. and electromagnetic sensors, and telecommunication. She can be contacted at email: merna@unhas.ac.id.