Design and Construction of an Officer Reminder System for Train Arrivals and Departures using Fiber Optic Media (PT KAI Operational Area 8 Surabaya)

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***Abstract*—Reliable communication between railway stations and level crossing officers is essential for ensuring train safety and operational efficiency. Conventional mechanical bell systems have limited communication reliability and require frequent maintenance. This study proposes the design and implementation of a fiber optic–based officer reminder system to provide real-time notifications of train arrivals and departures in PT Kereta Api Indonesia (PT KAI) Operational Area 8 Surabaya. The proposed system integrates Arduino Uno controllers with Ethernet Shields, fiber optic media converters, and audio-visual signaling modules to establish communication between Lamongan Station, Surabayan Station, and connected level crossing posts (JPL). System performance was evaluated through field implementation using Quality of Service (QoS) parameters measured with Wireshark. The experimental results showed an average delay of 4.21 ms, jitter of 4.59 ms, packet loss of 0%, and throughput of 0.844 kbps. These results demonstrate that the proposed system provides stable, reliable, and low-latency communication suitable for railway signaling applications. The implementation of optical fiber communicationimproves notification accuracy, enhances operational coordination between stations and level crossing officers, and offers a more reliable alternative to conventional mechanical bell systems for supporting safe and efficient railway operations.**

***Keywords*—Arduino Uno, Fiber optic communication, Officer reminder system, Quality of Service (QoS), Railway communication system.**

I. INTRODUCTION

Railway transportation has become one of the most reliable modes of land transportation due to its ability to provide high-capacity, energy-efficient, and safe passenger and freight services. As railway traffic continues to increase, communication systems play a fundamental role in ensuring operational safety, train punctuality, and coordination among railway personnel. Modern railway operations require continuous and real-time information exchange between station operators, signaling equipment, and level crossing officers to minimize operational delays and reduce the possibility of accidents [1], [2].

In Indonesia, PT Kereta Api Indonesia (PT KAI) operates an extensive railway network consisting of stations, signaling systems, communication facilities, and level crossings distributed across different operational regions. The coordination between the Railway Traffic Controller (Pengatur Perjalanan Kereta Api/PPKA) and the level crossing officer (Penjaga Jalan Lintasan/PJL) is one of the most critical operational activities because every train arrival and departure must be communicated accurately and promptly to guarantee traffic safety [3], [4]. However, field observations and technical interviews conducted at the Signaling and Telecommunication Workshop of PT KAI Operational Area 8 Surabaya indicate that several railway sections still employ conventional mechanical bell systems as the primary communication medium between stations and level crossings [5], [6].

Mechanical bell communication systems have been utilized for decades because of their simple operating principle and relatively low installation cost. Nevertheless, these systems suffer from several technical limitations, including dependence on copper transmission cables, signal attenuation over long distances, susceptibility to electromagnetic interference, and degradation caused by environmental conditions such as humidity and lightning. Furthermore, aging communication equipment and the decreasing availability of replacement components increase maintenance costs and reduce operational reliability [5], [7]. As railway operations continue to evolve toward higher train frequencies and stricter safety requirements, conventional communication methods become increasingly inadequate for supporting reliable and real-time operational coordination.

Optical fiber communication has emerged as one of the most promising technologies for railway communication systems because it offers significantly higher bandwidth, lower attenuation, longer transmission distance, and complete immunity to electromagnetic interference compared with conventional copper-based media [8], [9]. The implementation of fiber optic infrastructure has been widely adopted in modern transportation systems to improve communication reliability and network availability while reducing maintenance requirements. Previous studies have demonstrated that fiber optic networks can effectively support railway communication and signaling applications with excellent transmission performance [8], [10]. Similarly, the integration of optical fiber communication with axle counter–based signaling systems has been reported to improve operational safety and signaling reliability in railway block systems [11].

Recent developments in embedded systems have also enabled the implementation of low-cost intelligent communication devices using microcontrollers such as Arduino Uno combined with Ethernet-based communication modules. Arduino platforms provide flexible hardware integration, low power consumption, and compatibility with industrial Ethernet communication, making them suitable for distributed monitoring and control applications [12], [13]. When integrated with fiber optic transmission media, embedded controllers can establish stable communication networks capable of delivering real-time operational information between geographically separated railway facilities.

The performance of communication systems is commonly evaluated using Quality of Service (QoS) parameters, including delay, jitter, throughput, and packet loss. These parameters quantitatively measure communication reliability, transmission efficiency, and network stability under actual operating conditions. Previous comparative studies have shown that optical fiber communication consistently provides lower delay, smaller jitter, and more stable transmission than conventional copper-based Ethernet networks, making it highly suitable for mission-critical communication applications [14], [15].

Although numerous studies have investigated fiber optic deployment for railway communication networks and signalling infrastructure, most of them primarily focus on network design, transmission analysis, or signalling modernization. Limited attention has been given to developing an integrated officer reminder system capable of automatically delivering real-time train arrival and departure notifications directly from railway stations to level crossing officers using fiber optic communication. Moreover, previous studies rarely evaluate the operational performance of such systems through field implementation using Quality of Service measurements.

Therefore, this study proposes the design and implementation of a fiber optic–based officer reminder system for train arrivals and departures in PT Kereta Api Indonesia Operational Area 8 Surabaya. The proposed system integrates Arduino Uno controllers, Ethernet Shields, fiber optic media converters, and audio-visual signalling devices to establish reliable communication between Lamongan Station, Surabayan Station, and multiple level crossing posts. The system performance is experimentally evaluated using Quality of Service analysis through Wireshark by measuring delay, jitter, throughput, and packet loss. The proposed system is expected to provide a practical, reliable, and cost-effective communication solution that enhances operational coordination, improves notification accuracy, and supports safer railway operations.

II. METHOD

A. Research Method

This research adopted an engineering design methodology consisting of system analysis, hardware and software development, communication network implementation, system integration, and experimental evaluation. The objective was to replace the conventional mechanical bell communication system with a fiber optic–based officer reminder system capable of delivering real-time train arrival and departure notifications between railway stations and level crossing posts. Research methodology flowchart shown on Fig. 1.

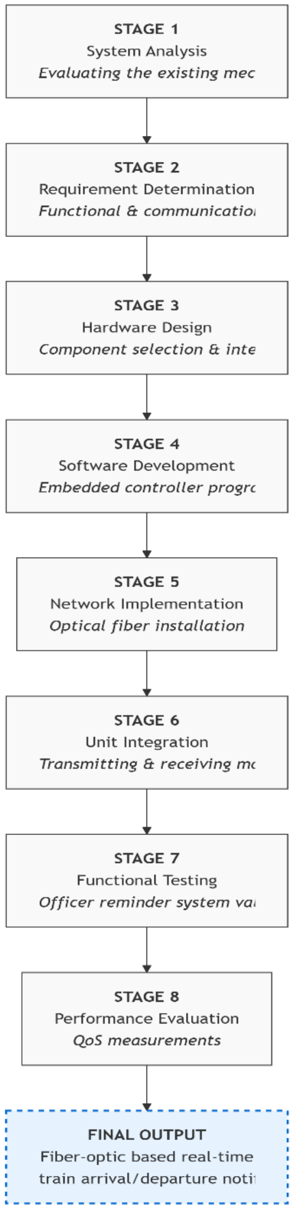

Figure 1. Research methodology flowchart for the proposed fiber optic-based officer reminder system.

The overall research procedure consists of the following stages:

1) Analysis of the existing railway communication system.
2) Determination of functional and communication requirements.
3) Hardware design and component integration.
4) Software development for embedded controllers.
5) Optical fiber communication network installation.
6) Integration of transmitting and receiving units.
7) Functional testing of the officer reminder system.
8) Performance evaluation using Quality of Service (QoS) measurements.

Each stage was completed sequentially to ensure that the developed system satisfied the operational requirements of railway communication.

The research was conducted at PT Kereta Api Indonesia (PT KAI) Operational Area 8 Surabaya, covering Lamongan Station, Surabayan Station, and several connected level crossing posts (JPL).

B. *Existing Communication System Analysis*

The initial stage involved analyzing the conventional officer reminder system currently used in the railway communication network. In the existing system, train movement information is transmitted through a mechanical bell connected by copper communication cables between adjacent stations and level crossing posts.

When a train departs from a station, the Railway Traffic Controller (PPKA) manually operates the mechanical bell by rotating the transmission lever according to a predefined signaling pattern. The generated bell sound is then received by the officer at the destination station or level crossing.

Although this communication mechanism has been employed for many years, several operational limitations were identified during field observations, including:

- dependence on aging copper communication cables,
- susceptibility to electrical interference,
- limited transmission reliability,
- frequent maintenance requirements,
- manual operating procedures,
- reduced communication efficiency over long transmission distances.

These limitations motivated the development of a communication system based on fiber optic technology.

C. *System Architecture*

The proposed officer reminder system consists of a transmitting unit, a optical fiber communication network, and a receiving unit.

The transmitting unit is installed at the railway station and functions as the notification controller operated by the Railway Traffic Controller (PPKA). The receiving unit is installed at the destination station or level crossing post (JPL), where train notifications are delivered through audible and visual warning devices.

Communication between both locations is established through Ethernet communication over a fiber optic network using media converters [8], [10].

D. *Hardware Design*

The hardware configuration was designed using commercially available embedded devices to simplify maintenance and future system expansion. The hardware design block diagram is depicted in Fig. 2.

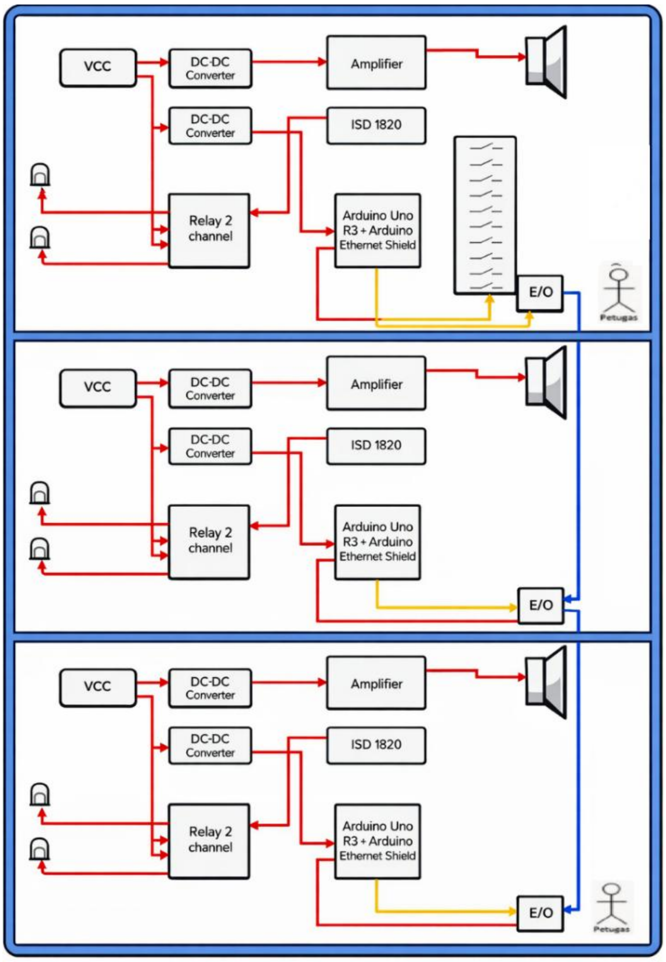

Figure 2. Block diagram of the transmitting and receiving nodes used in the officer reminder system.

The transmitting unit consists of: Arduino Uno microcontroller, Arduino Ethernet Shield, Push-button interface, Fiber optic media converter, DC–DC converter (12 V to 7 V), and Power supply.

The receiving unit consists of: Fiber optic media converter, Arduino Uno, Arduino Ethernet Shield, Two-channel relay module, ISD1820 voice recording module, Audio amplifier, Loudspeaker, DC–DC converter, and Power supply.

The DC–DC converter provides stable operating voltage for all electronic components. The relay module functions as an electrical interface between the Arduino controller and the voice module. Meanwhile, the ISD1820 module stores prerecorded railway bell sounds representing train arrival and departure notifications.

Compared with conventional mechanical bell equipment, this configuration significantly reduces mechanical wear while improving communication reliability.

E. Software Design

The embedded software was developed using the Arduino Integrated Development Environment (Arduino IDE). Two independent programs were developed for the transmitting and receiving units.

At the transmitting node, the software continuously monitors the status of the push buttons. When a button is pressed, Arduino generates a predefined command packet containing the notification type and transmits it through the Ethernet Shield.

At the receiving node, Arduino continuously listens for incoming Ethernet packets. After validating the received command, the controller activates the corresponding relay output, which triggers the ISD1820 voice module to play the prerecorded notification sound. Simultaneously, the warning indicator remains active until the playback process is completed.

This software architecture ensures automatic operation without requiring manual intervention after the initial notification is transmitted [17].

F. Officer Reminder Mechanism

Unlike the conventional communication system that requires railway personnel to operate a mechanical bell manually, the proposed system replaces this procedure with an automatic digital notification process.

For train departure notifications, the station operator presses the departure button. The command is transmitted through the fiber optic network and automatically activates the prerecorded departure bell at the destination. Similarly, train arrival notifications are generated by pressing the arrival button, which initiates the same communication procedure but activates the corresponding arrival notification sound.

The use of prerecorded audio stored in the ISD1820 module ensures that every notification is delivered with consistent sound quality and eliminates variations caused by manual operation.

G. Fiber Optic Communication Network

The communication infrastructure employs single-mode fiber optic cable as the primary transmission medium.

Each communication node is connected through Ethernet-based fiber optic media converters operating in point-to-point communication mode. Optical transmission was selected because of its high bandwidth, low attenuation, immunity to electromagnetic interference, and long transmission capability.

Static IP addressing was configured on every Ethernet Shield to simplify communication management and improve transmission stability. Compared with conventional copper communication cables, the fiber optic network offers significantly higher communication reliability for railway operational environments.

H. Experimental Setup

System validation was performed through direct implementation in PT KAI Operational Area 8 Surabaya. The experimental setup connected Lamongan Station, Surabayan Station, and the associated level crossing posts using the proposed fiber optic communication network. Several train arrival and departure scenarios were repeatedly executed to verify the operational functionality of the reminder system.

Network communication was monitored using Wireshark to capture all transmitted Ethernet packets during the experiments. The captured data were subsequently analyzed to evaluate communication performance.

I. Quality of Service Evaluation

Communication performance was evaluated using four Quality of Service (QoS) parameters.

1) Delay: Delay represents the elapsed time required for a packet to travel from the transmitting node to the receiving node.

$$\text{Delay} = \frac{\sum_{i=1}^{n} ti}{n} \tag{1}$$

where t_i is the transmission delay of packet *i* and *n* is the total number of transmitted packets.

2) Jitter

Jitter measures the variation in packet delay during communication.

$$\text{Jitter} = \frac{\sum_{i=1}^{n-1} |delay_{i+1} - delay_{i-1}|}{n-1} \tag{2}$$

Smaller jitter values indicate more stable communication performance.

3) Packet Loss

Packet loss is defined as the percentage of transmitted packets that fail to reach the destination.

$$\textit{Packet Loss} = \frac{Packets_{sent} - Packets_{receive}}{Packets_{Sent}} \tag{3}$$

An ideal communication system should achieve a packet loss value approaching zero.

4) Throughput

Throughput indicates the effective amount of successfully transmitted data within a given transmission period.

$$\textit{Throughput} = \frac{Total\ Data\ Received}{Transmission\ Time} \tag{4}$$

The throughput value is expressed in kilobits per second (kbps).

J. Data Analysis

The measured QoS parameters were compared with acceptable communication performance criteria to determine the suitability of the proposed system for railway operations. In addition to network performance, functional testing was conducted to verify the accuracy of notification delivery, response time, synchronization between transmitting and receiving units, and the stability of the audio notification system.

The overall system performance was assessed based on its ability to provide reliable, low-latency, and error-free communication between railway stations and level crossing officers. These evaluation results form the basis for determining the feasibility of replacing the conventional mechanical bell system with the proposed fiber optic–based officer reminder system.

III. RESULTS AND DISCUSSION

The proposed officer reminder system was successfully implemented in the communication network of PT Kereta Api Indonesia (PT KAI) Operational Area 8 Surabaya. The implementation involved the integration of embedded controllers, Ethernet communication modules, fiber optic transmission media, and audio notification devices to establish real-time communication between Lamongan Station, Surabayan Station, and the associated level crossing posts (JPL).

A. *Functional Testing*

Functional testing was conducted after completing the hardware installation and software integration. The objective was to verify that every subsystem operated according to the intended design before communication performance evaluation.

1) Departure Notification Test: The departure notification test evaluated the ability of the transmitting node to send departure commands through the fiber optic network. During the experiment, the Railway Traffic Controller (PPKA) pressed the departure button installed at the transmitting station.

The Arduino Uno immediately detected the input signal and generated an Ethernet packet containing the departure notification command. The packet was transmitted through the Ethernet Shield and converted into an optical signal by the media converter before being delivered through the fiber optic cable.

At the receiving node, the optical signal was converted back into an Ethernet packet and processed by the Arduino controller. The relay module was then activated, triggering the ISD1820 voice recording module to reproduce the prerecorded departure bell sound. The audio amplifier increased the signal level before it was broadcast through the loudspeaker.

The experimental results confirmed that every departure command was successfully delivered without communication failure, indicating correct operation of the transmitting and receiving hardware.

2) Arrival Notification Test: The arrival notification test followed the same communication procedure as the departure notification. The Railway Traffic Controller activated the arrival button, generating an arrival notification packet.

The communication process was completed successfully through the fiber optic network, and the receiving unit reproduced the prerecorded arrival notification sound immediately after receiving the command.

Repeated experiments demonstrated consistent communication performance without missing notifications, confirming that the proposed system can reliably distinguish between arrival and departure events.

3) Audio Notification Verification: The ISD1820 voice recording module stored prerecorded railway bell sounds corresponding to train arrival and departure notifications.

During testing, every received command correctly activated the appropriate audio recording. The audio amplifier successfully increased the output signal level, allowing the loudspeaker to produce clear notification sounds audible to the level crossing officer.

No synchronization errors or incorrect audio playback were observed during repeated testing, demonstrating reliable coordination between the embedded controller, relay module, and voice recording device.

4) Communication Reliability: Communication reliability was evaluated by repeatedly transmitting notification packets between stations and level crossing posts.

Throughout the experiments, every command transmitted from the station was successfully received at the destination node. No communication interruption, retransmission, or packet corruption was observed during normal operating conditions.

These functional test results demonstrate that the proposed officer reminder system operates reliably and is capable of replacing the conventional mechanical bell communication mechanism.

B. *Quality of Service Evaluation*

Following successful functional verification, the communication network was evaluated using Quality of Service (QoS) analysis. Network traffic generated during the notification process was captured using Wireshark, and communication performance was analyzed using four standard QoS parameters: delay, jitter, packet loss, and throughput.

1) Delay Performance: Delay represents the transmission time required for a notification packet to travel from the transmitting node to the receiving node. Based on the Wireshark measurements displayed in Fig. 3

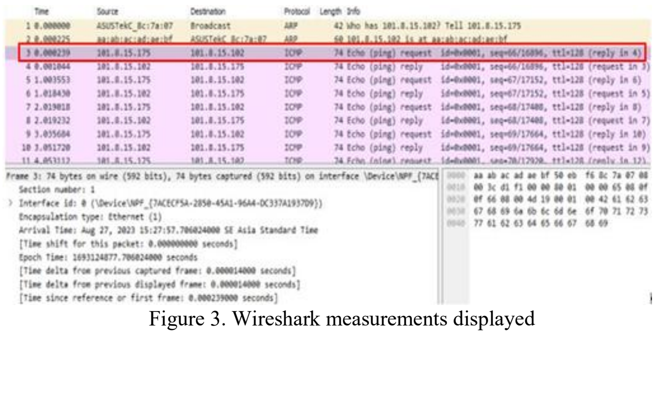

Figure 3. Wireshark measurements displayed

Wireshark measurements displayed in Table I, the proposed communication system achieved an average end-to-end delay of 4.20976ms. This value indicates that notification packets were delivered almost instantaneously after transmission. Considering the operational requirements of railway communication systems, a delay of approximately 4 ms is sufficiently low to support real-time train arrival and departure notifications.

TABLE I
DELAYED RESULTS

No.	Reply Time (s)	Request Time (s)	Delay (s)
1	0.001044	0.000239	0.000805
2	1.018430	1.003553	0.014877
3	2.019232	2.019018	0.000214
4	3.051720	3.035684	0.016036
5	4.053713	4.053112	0.000601
6	5.069003	5.068793	0.000210
7	6.105729	6.089176	0.016553
8	7.107472	7.107248	0.000224
9	11.172776	11.172579	0.000197
10	12.178344	12.178058	0.000286
11	13.200137	13.199908	0.000229
12	14.221055	14.220770	0.000285

The results of the delay calculations in this study can be categorized as "very good" [16], where the delay time obtained is 4.20975 ms, which is less than ≤ 150 ms or has an index of 4.

2) Jitter: Jitter represents the variation in packet transmission delay during communication. The experimental results as shown at Table II.

TABLE II
JITTER RESULTS

No.	Reply Time (s)	Request Time (s)	Delay (s)
1	0.001044	0.000239	0.000805
2	1.018430	1.003553	0.014877
3	2.019232	2.019018	0.000214
4	3.051720	3.035684	0.016036
5	4.053713	4.053112	0.000601
6	5.069003	5.068793	0.000210
7	6.105729	6.089176	0.016553
8	7.107472	7.107248	0.000224
9	11.172776	11.172579	0.000197
10	12.178344	12.178058	0.000286
11	13.200137	13.199908	0.000229
12	14.221055	14.220770	0.000285

The experimental results produced an average jitter of 4.59245 ms. The relatively small variation indicates that packet transmission remained stable throughout the experiment.

Stable jitter performance is particularly important in railway communication because inconsistent transmission timing may delay notification delivery and reduce operational coordination. The obtained jitter value confirms that the optical fiber communication network provides consistent packet transmission under actual operating conditions.

3) Packet Loss Evaluation: Packet loss measures the percentage of transmitted packets that fail to reach the receiving node. Experimental measurements showed at Table III, a packet loss value of 0 %, indicating that every transmitted notification packet successfully arrived at its destination. Therefore, Lamongan Station's packet delivery can be categorized as very good, with an index value of 4 for the inter-circuit transmission process.

TABLE III
PACKET LOSS RESULT

No.	Reply Time (s)	Request Time (s)	Delay (s)
1	0.001044	0.000239	0.000805
2	1.018430	1.003553	0.014877
3	2.019232	2.019018	0.000214
4	3.051720	3.035684	0.016036
5	4.053713	4.053112	0.000601
6	5.069003	5.068793	0.000210
7	6.105729	6.089176	0.016553
8	7.107472	7.107248	0.000224
9	11.172776	11.172579	0.000197
10	12.178344	12.178058	0.000286
11	13.200137	13.199908	0.000229
12	14.221055	14.220770	0.000285

4) Throughput: Throughput represents the effective data transmission rate achieved during communication. The experimental results shown in Table IV.

TABLE IV
THROUGHPUT RESULT

No.	Reply Time (s)	Request Time (s)	Delay (s)
1	0.001044	0.000239	0.000805
2	1.018430	1.003553	0.014877
3	2.019232	2.019018	0.000214
4	3.051720	3.035684	0.016036
5	4.053713	4.053112	0.000601
6	5.069003	5.068793	0.000210
7	6.105729	6.089176	0.016553
8	7.107472	7.107248	0.000224
9	11.172776	11.172579	0.000197
10	12.178344	12.178058	0.000286
11	13.200137	13.199908	0.000229
12	14.221055	14.220770	0.000285

The experimental results yielded an average throughput of 0.844 kbps. Although the throughput value appears relatively small compared with multimedia communication systems, it is appropriate for the proposed application because the system transmits only short Ethernet command packets rather than continuous multimedia data streams.

C. Discussion

The experimental results demonstrate that the proposed officer reminder system successfully integrates embedded controllers, Ethernet communication, and fiber optic transmission into a reliable railway communication platform.

Compared with the conventional mechanical bell system, the proposed approach eliminates manual lever operation by replacing it with digital notification commands transmitted over a fiber optic network. This modification reduces mechanical wear, minimizes maintenance requirements, and improves communication consistency.

The QoS measurements further validate the effectiveness of the communication infrastructure. The average delay of 4.20976 ms ensures rapid notification delivery, while the jitter value of 4.59245 ms indicates stable packet transmission. Moreover, the absence of packet loss confirms highly reliable communication between stations and level crossing posts. Although the measured throughput is relatively low, it is entirely adequate for transmitting compact notification commands, making the communication process both efficient and reliable.

The integration of the Arduino Uno, Ethernet Shield, fiber optic media converters, relay module, ISD1820 voice recording module, and audio amplifier proved effective in implementing an automated officer reminder mechanism. Functional testing confirmed that both train arrival and departure notifications were delivered accurately, and the corresponding audio signals were reproduced without synchronization errors.

Overall, the proposed system provides a practical alternative to the conventional mechanical bell communication system. By combining optical fiber communication with embedded Ethernet-based controllers, the developed system improves notification accuracy, communication reliability, and operational efficiency while supporting safer coordination between railway stations and level crossing officers. These findings are consistent with the objective of developing a modern, real-time communication system capable of meeting the operational requirements of railway signaling applications. It means using fiber optic digital communication is a good idea for improving railway signals in PT KAI DAOP 8 Surabaya.

IV. CONCLUSION

This study successfully designed, implemented, and evaluated a fiber optic–based officer reminder system for train arrival and departure notifications in the railway communication network of PT Kereta Api Indonesia (PT KAI) Operational Area 8 Surabaya. The proposed system integrates Arduino Uno microcontrollers, Ethernet Shields, fiber optic media converters, relay modules, ISD1820 voice modules, audio amplifiers, loudspeakers, and visual indicators to replace the conventional mechanical bell communication system with a digital, Ethernet-based communication platform. Experimental results demonstrated that the developed system operated reliably under actual railway operating conditions. The functional tests confirmed that train arrival and departure notifications were transmitted accurately between railway stations and level crossing posts without communication failures. Quality of Service (QoS) evaluation further verified the effectiveness of the communication network. The average delay was 4.20976 ms at Lamongan Station and 0.2765 ms at the level crossing (JPL), while the corresponding jitter values were 4.59245 ms and 0.36867 ms, respectively. In addition, the communication achieved 0% packet loss at both locations, with throughput values of 0.844 kbps at Lamongan Station and 1.324 kbps at the JPL. These results indicate that the proposed system provides low-latency, stable, and highly reliable communication suitable for real-time railway signaling applications. Overall, the implementation of fiber optic communication significantly improves the accuracy, reliability, and operational efficiency of train notification delivery compared with the conventional mechanical bell system. The proposed officer reminder system therefore offers a practical and scalable solution for modernizing railway communication infrastructure and enhancing operational safety at railway stations and level crossings.

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