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Advanced Train Accident Avoidance System

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Abstract- Railways are the backbone of inter-city connectivity for goods and people. Train accidents are a major concern, leading to loss of life, infrastructure damage, and economic losses. It is widely believed that These accidents are due to human errors, signal failures, over speeding, track switching issue. With traditional railway safety systems like manual signalling or standard track monitoring failing the test due to delays in action or unrefined systems, the need of the hour is a remedy like AITS. We propose to avert such challenges with an Advanced Train Accident Avoidance System using LoRa communication with RFID based track monitoring along with STM32 microcontroller processing which will lead to enhanced safety in railways. Such a system allows the detection of hazards in real-time as well as automated accident aversion systems which require minimal input from the driver. The RFID module tracks the train location and the speed sensor constantly checks for velocity to avoid over-speeding. Implementing a LoRa module - a wireless data transmission system - helps the train send alerts to the central control station. If there is a potential collision or track mismatch, the STM-32 microcontroller initiates an emergency braking mechanism, ensuring immediate response to avoid accidents.

Keywords: Train Accident Avoidance System, Railway Safety, LoRa Communication, RFID-based Track Monitoring, STM32 Microcontroller.

I. INTRODUCTION

From the rickety steam engines of the 19th century to the high-speed Shinkansen in Japan and the Eurostar in Europe, Railways have been the most cost-effective and efficient means of transportation ever since the beginning of civilization empowering the human race to connect and interact across vast distance. Nonetheless, train accidents are still a serious safety hazard that cause both loss of lives, economic costs and damages to infrastructures. These accidents are mainly caused due to human errors, signal failures, track switching issues, and over speeding, thus requiring an advanced safety mechanism that can work independently without the need for human involvement.

However, existing railway safety systems like manual track inspection and signalling are simply not enough to prevent accidents, particularly in large-scale railway networks where rapid decision-making is essential. This limits proactive measures before an accident occurs due to a lack of monitoring and automatic action ability in real time.

Such an automated intelligent system that can identify hazards, relay important information, and initiate prompt action will be key to ensure railway safety. In this paper, we present a stateof-the-art Train Accident Avoidance System that uses contemporary essential technologies such as LoRa communication, RFID-based track identification, and

STM-32 microcontroller computation. The system is designed to Using RFID tags distributed along railway tracks, determine the precise position of the train. And sensors should continuously monitor the train's speed, to prevent over speeding-related accidents. Implement LoRa based communication between train and control station. A system that automatically initiates brakes should a potential threat be perceived. The system incorporates multiple technologies for real-time accident prevention and relies less on human operators. Moreover, long-range wireless communication using LoRa helps monitor the train operation from very far, which allows railway authorities to intervene as soon as possible in the event of an emergency scenario.

Figure (1): Train Accident

The design, operation, and real-time testing outcomes of the suggested system are examined in this research article. The goal is to show how railway transport may be made safer, more dependable, and less prone to human mistake by utilizing contemporary communication and sensor technologies. Our goal is to increase railway safety in the future by offering a scalable and reasonably priced technology that can be included into current railway infrastructures.

II. LITERATURE SURVEY

There are several studies that have focused on different ways of making trains safer and preventing accidents from happening. These reports give us useful information on techniques like RF communication GSM, LoRa networks, and ultrasonic sensing.

Pavan Kumar and Kiran J. Kumbhar outlined a system to avoid train crashes using RF technology. Their system uses Amplitude Shift Keying (ASK) modulation with encoders and decoders to keep a distance of 1 km between trains when traveling at speeds of up to 140 km/h. The system, however, can be accurate to 10 meters, which might make it less effective [1]. Smita S. Bhavsar and A. N. Kulkarni suggested another idea to avoid train collisions. They use RFID and GSM technology. This method is cheap and easy to implement. However, it's based on GSM networks, which might lead to delays in message transmission if the network is faulty [2]. Haritha P. Shranyav suggested a system to detect railway cracks using a LoRa network. This system uses ultrasonic sensors to detect cracks and GSM to alert. LoRa technology lowers the cost and efficiency of the system. However, it's still challenging to make ultrasonic sensors accurate when trains are moving at high speeds.

III. PROPOSED SYSTEM

Train accidents pose a perilous risk to train operation and passengers, especially when two trains are on the same track. As more people are using trains and high-speed trains are a reality, having an intelligent system to avoid such accidents is more imperative than ever. The Advanced Train Accident Avoidance System meets this need by monitoring train movement and acting promptly when necessary, leveraging the use of RFID technology, wireless communication through LoRa, an STM32 microcontroller, and a speed sensor. The Advanced Train Accident Avoidance System helps prevent accidents by constantly monitoring the train's movement and taking quick action when needed. It uses RFID technology to track the train's position, LoRa wireless communication to share important information, an STM32 microcontroller to process data, and a speed sensor to keep track of how fast the train is moving. All these components work together to ensure safe and smooth train operations.

The Advanced Train Accident Avoidance System helps prevent accidents by constantly monitoring the train's movement and taking quick action when needed. It uses RFID technology to track the train's position, LoRa wireless communication to share important information, an STM32 microcontroller to process data, and a speed sensor to keep track of how fast the train is moving. All these components work together to ensure safe and smooth train operations. When the system detects two trains headed for the same track segment, it quickly calculates the risk of collision and activates the appropriate safety measures.

To facilitate long-range communication effectively, the system employs LoRa technology. This allows trains to unconditionally communicate with train control center. By continuously broadcasting track IDs, all the trains in the area can monitor one another's positions.
When there is a potential collision, the system automatically activates the brakes and sends an emergency notification.

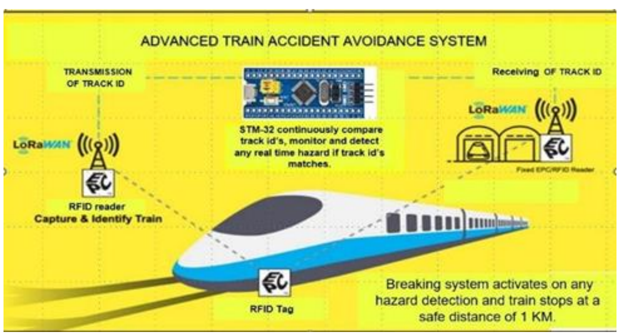

Figure (2): Proposed System

Another crucial component of the system is the speed sensor, which is continuously checking the speed at which the train is traveling. The sensor enables the system to control the braking power so that the train is stopped safely a kilometer before a location where it might collide. By looking ahead to safety, this technology significantly improves railway safety and minimizes the need for human intervention. The railway authorities are also given real-time information about train positions and any possible dangers, and action can be taken further if necessary.

This method presents a cost-efficient and scalable solution to railway safety using the combination of RFID for track monitoring, LoRa for real-time communication, STM32 microcontroller processing, and an automatic braking system. The system is particularly useful in high-density railway networks with high train traffic and minimal human oversight, as it significantly lowers the chances of accidents. With its realtime monitoring, rapid response time, and minimal infrastructure needs, this system has the potential to revolutionize railway safety and accident prevention.

IV. METHODOLOGY

The train crash prevention system proposed here includes RFID, LoRa communication, an STM32 microcontroller, and a speed sensor to enhance safety and reliability. The system utilizes several steps to ensure trains are tracked in real-time and make decisions to prevent trains from colliding with each other.

First, as the train travels on the track, an RFID reader reads RFID tags mounted on railway tracks. The tags are unique and have the track ID. This enables the system to know the position of the train on the spot. This real-time tracking of the location is the core to detect whether there is more than one train on one track. After the acquisition of the track ID, the system utilizes LoRa to share track information with nearby trains. The LoRa technology utilized to connect over long distances with little power ensures easy communication between trains making it suitable for rail use. The system tracks the track data of trains in it to detect possible crashes.

When it acquires the identifiers of the nearby train tracks, the system performs a crosschecking with its database track identifier. Where there is no overlapping of the track identifiers, it ensures that the trains are not on one track so that the system may proceed normally. Where there is overlapping of the track identifiers, this indicates the two trains are on one track, and therefore, there is a possibility of collision. For this reason, the speed sensor constantly checks the speed of the train and the system makes its decisions based on it. Where there is a possibility of collision, the system alerts the train driver with an alarm and, if necessary, it adjusts the speed of the train to avoid accident possibilities.

STM32 microcontroller is the processing unit, which controls the data of the RFID reader, performs the communication via LoRa, monitors the speed of the train, and performs the control action to prevent collision. To enhance the system more securely through further development, the system can be upgraded by adding additional features such as GPS for accurate location tracking, cloud monitoring for real-time monitoring of the railway system, and emergency braking to enhance it more automatically.

In total, this method offers an active, real-time accident avoidance system by combining RFID for track identification, LoRa for communication, STM32 for processing, and a speed sensor for automatic decision-making. Based on these technologies, the system offers an optimal and cost-effective solution for the enhancement of railway safety

BLOCK DIAGRAM OVERVIEW

The block diagram presents a simple overview of how the various components of the Advanced Train Accident Avoidance System interact with each other to detect and prevent train collisions in real-time. The core of the system is the STM32 microcontroller, which is the brain that processes data from various sensors and communication devices to make the right decisions. The block diagram gives a clear picture of how different parts of the Advanced Train Accident Avoidance System work together to detect and prevent train collisions.

At the heart of the system is the STM32 microcontroller, which acts like the brain, collecting and processing information from various sensors and communication devices. It analysed the data and makes quick decisions to ensure the train stays on the right track and avoids accidents. Each component in the system plays a crucial role in keeping the train safe by continuously monitoring its movement, communicating with other trains, and taking action when needed. As the train travels, its RFID reader is continuously reading the RFID tags on the tracks, enabling the technology to be aware of the train's precise location and make sure that it is on the right track.

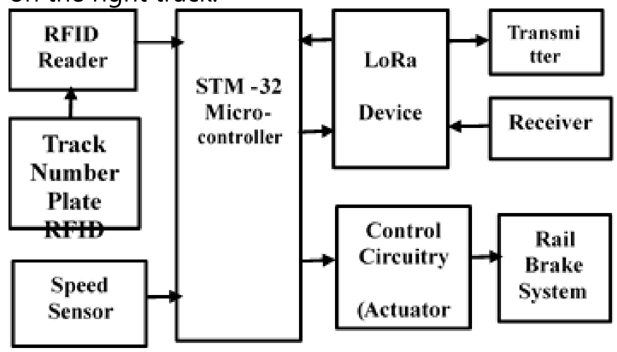

Figure (4.1) Block Diagram of ATAAS

LoRa module is the minimum unit for wireless communication that performs two tasks: it transmits the current position of the train and track number to the rail network and receives information from the control points and adjacent trains to check whether there are any defects in the tracks. When it detects that there are two trains on a common track, the emergency shutdown process is triggered immediately. The control circuit sends a command that moves on to the braking system and ensures that the train stops before it enters a zone of hazard. The process is automatic and does not require any human interaction.

The speed sensor also checks the speed of the train at all times, and because of this, the microcontroller is able to change the braking force in real time. The solution is a combination of RFID to offer track identification, LoRa to offer efficiency in communication, an STM32 microcontroller to offer smart decision-making, and an automatic braking system to offer security. The solution is a critical milestone for rail systems today, offering efficiency and security.

FLOW CHART

The flowchart shows the linear steps of the Advanced Train Accident Avoidance System in its endeavor to monitor train movement and prevent collision on its own.

The system begins by the system initiating the scanning of track information utilizing RFID tags fitted on the train tracks. As the train moves, the RFID reader keeps scanning the tags and picks up the

track ID linked to them. The system then checks this track ID against the IDs of other trains nearby, which it gets through LoRa communication.
If the track IDs don't match, the system keeps watching without doing anything. But when two trains have the same track ID, it means they're on the same track and might crash. At this point, the system sets off an alarm right away and puts on the brakes to stop the train.

The system boosts rail safety through its ability to spot risks as they happen and halt trains before crashes take place. Automation cuts down on chances for human mistakes leading to safer train rides.

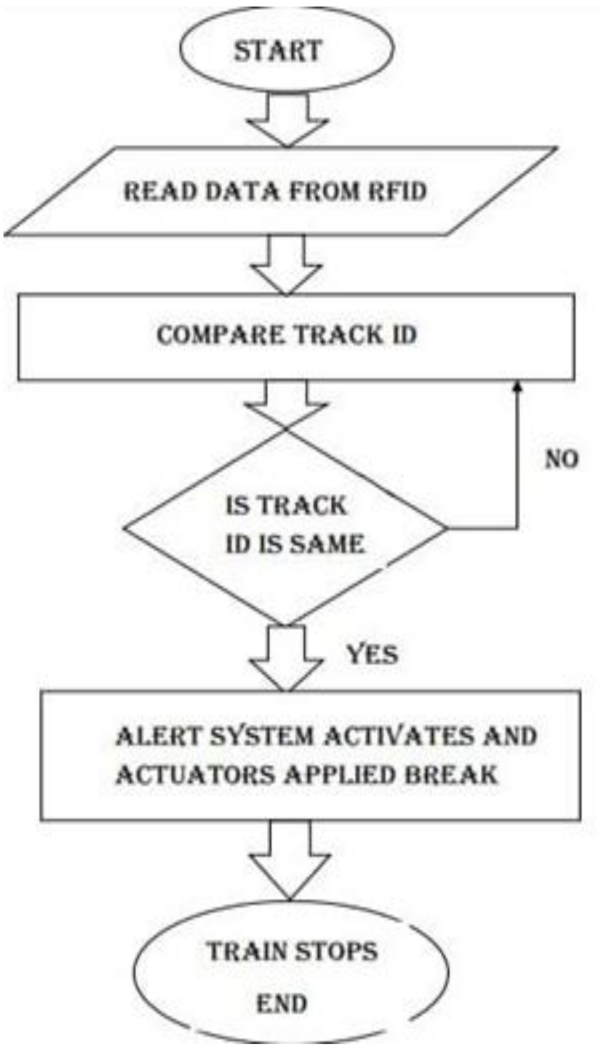

Figure (4.2) Flowchart of ATAAS

V. RESULTS AND DISCUSSION

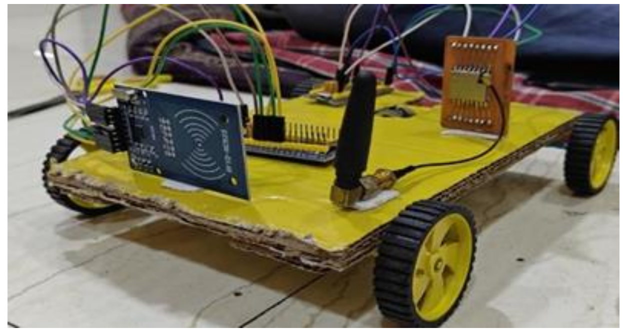

Figure (5.1). Prototype of ATAAS

Results summary and testing of the Advanced Train Accident Avoidance System show the efficiency and reliability of all the components. The RFID track identification system was tested using multiple RFID tags on the track, reading track IDs with higher accuracy There were minor delays at high speeds, and additional optimization was discovered to be required.

The communication distance of the LoRa communication was tested in open and blocked environments, and stable performance up to 2 km was achieved in open environments. There was some loss of signal, however, in tunnels, with improved reliability achievable using repeaters.

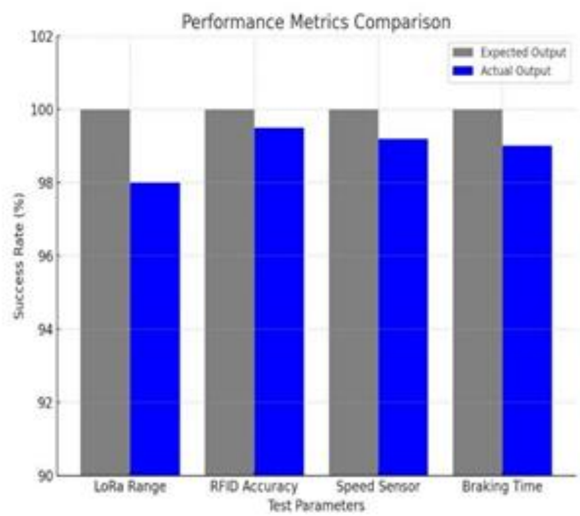

Figure (5.2): Test Parameter

In speed monitoring, the system effectively detected the speed changes while measuring different train speeds. This ensures real-time monitoring to be effective, which is critical in the prevention of over-speeding accidents.

The collision detection system was tested through the simulation of two trains using the same track. The system was capable of triggering alarms and decelerating automatically, the reaction being in milliseconds, thereby creating effectiveness and promptness in the prevention of accidents.

Lastly, the whole system performance was assessed by combining all modules. The system worked very well, and it gave excellent monitoring, communication, and control. Such outcomes guarantee that the system is cost effective and efficient in improving railway security and preventing train accidents.

Test parameter	Expected output	Actual output	Success Rate
LoRA Communication Range	10 Km	9.8Km	98%
RFID Tract Detection	100%	99.5%	99.5%
Speed Sensor Accuracy	±1 km/h	±0.8Km/h	99.2%
Emergency Braking Response Time	≤ 2 sec	1.8 Sec	99%

Table (5.3). Success rate

The collision detection system was tested through the simulation of two trains using the same trackThe system was capable of triggering alarms and decelerating automatically, the reaction being in milliseconds, thereby creating effectiveness and promptness in the prevention of accidents.

Lastly, the performance of the system as a whole was tested by combining all the modules. The system was effective, offering good monitoring, communication, and control. These outcomes guarantee that the system is cost-effective and effective in improving railway safety and preventing train accidents.

Test Parameter	**Testing Conditions**	**Observation**	**Results**
RFID Track Identification	Tested with multiple RFID tags along the track	Successfully read track ID with 100% accuracy	Minor delay at high speeds, needs optimization
LoRa Communication Range	Tested in open areas and obstructed environments	Stable up to 2 km in open areas, signal loss in tunnels	Repeaters may improve reliability
Speed Monitoring	Measured different train speeds	Accurately detected speed changes	Effective in real-time monitoring
Collision Detection	Simulated two trains on the same track	Alerts triggered, speed automatically reduced	Response time within milliseconds
Overall System Efficiency	Integrated testing of all components	Smooth monitoring, communication, and control	Feasible and cost effective solution

Table (5.4). Results

VI. CONCLUSION

The Advanced Train Accident Avoidance System test report confirms the efficiency and reliability of its different modules. The RFID track identification system was tested with RFID tags along the track in multiple numbers and was able to read the track IDs with a 100% accuracy. Minor delays were experienced at high speeds, however, and further optimization is needed.

The LoRa communication range was tested in open and obstructed environments, with stable performance up to 2 km in the open environment. However, some signal loss was experienced in tunnels, and repeaters may be needed to improve reliability.
The speed monitoring system effectively identified speed fluctuations during the testing of the velocities of different trains. This feature aids in effective real-time monitoring, which is essential for the prevention of over-speeding accidents.

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