IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 4, June 2024

Train Collision Avoidance System with Wireless Communication

Aniket R. Shamraj[1] and A. D. Harale[2]
PG Scholar, Department of Electronics & Telecommunication Engineering[1]
Assistant Professor, Department of Electronics & Telecommunication Engineering[2]
SKN Sinhgad College of Engineering, Pandharpur, Maharashtra, India
avinashharale5@gmail.com

Abstract: *In India, human error and negligence are now the main causes of train accidents. The aim of the paper is to eliminate train crashes through the use of surveillance. An automatic surveillance system is fitted in every locomotive. The locomotive's internal surveillance system reads the distinct track numbers that are assigned to each segment of the railway network's train lines. This track number will be shared with neighbouring trains by the surveillance system via radio frequency communication. Subsequently, the system's track number is cross-referenced with the track numbers of adjacent trains. In order to halt the train and avoid accidents, the surveillance system acts to notify the concerned motorman of the same track numbers. A specific technique for numbering train tracks segment by segment is recommended by the study. In order to guarantee data flow between the systems' radio frequency transceivers operating in half duplex mode, a communication protocol is also suggested. Because they can move a lot of people and cargo at once, railways constitute an efficient mode of transportation. At either end of the branch track, Wireless Monitoring Units (WMUs), also known as nodes, are placed to allow for the detection of train arrival and departure times for that particular branch*

Keywords: Railway Line, Tracking System, Position Information, Ultrasonic Sensor, Wireless Sensor Networks, NRF2401

I. INTRODUCTION

There have been numerous rail accidents worldwide in recent times. In the last four months, human error has been the cause of 85% of train accidents, according to a CNN IBN India story dated September 14, 2011.Human error or technical faults resulting from inadequate maintenance are the main causes of these catastrophes. The suggested approach helps to mitigate some of the main train hazards. This approach suggests a low-cost, straightforward surveillance system to mitigate the hazards. This approach suggests a low-cost, straightforward surveillance system to mitigate the hazards. One of the most significant problems facing the world today in recent years is vehicle monitoring[1-5].

These days, tracking and monitoring trains is also a major crisis. Whenever a railway collision results in a significant loss of human life as well as significant financial and scheduling losses for the railway industry[6-8]. Our proposed system is a real-time wireless system that can track trains using both wired and wireless communication. It can also facilitate wireless communication between trains, allowing them to communicate track details and location information. Every train uses our system to indicate the track number it is travelling on[9-14].

Based on this, every train is able to determine how far away other trains are from them and, when they are moving on the same track and within a few kilometres of each other, to exchange emergency messages. The population is growing, and as a result, rail traffic is growing quickly. Numerous electromechanical devices are affected by an increase in rail traffic[15,16]. By allowing the generator to operate to full load before connecting the load, a delay circuit helps safeguard the appliances as well as the generating set. On the other hand, the power indicator lowers power costs because it uses less energy when running on the public power supply by providing the operator with both visual and aural signals when public power is restored[17-23].

This paper extends the life of the generator, protects the loads, increases power supply dependability, and does away with the need for human changeover by combining the twin responsibilities of automated conversion and progressive (gradually or step) loading[24,25]. It is impossible to overstate the significance of automatic changeover and step loaders, particularly in vital sectors like banking, telecommunications, defence, and healthcare where constant[26].

The operation of the Raspberry Pi-based wireless-based collision prevention device for the railway sector is vital, and a power outage has dire repercussions. To guarantee that power is applied to each load gradually, an orderly loader is employed[27]. This is to make sure that the generator is not overloaded in addition to providing power to the load. This gadget causes train collisions and derailments. Collisions frequently occur as a result of a train using an identical railway track or a technical issue. Many systems have been designed to address this. However, they are constructed with the errors made by the locomotive pilot in mind[28]. However, it is never the result of LP's errors[29].

Broken tracks can be the cause of several accidents. Our proposed solution aims to prevent collisions and derailments caused by cracks or fractures in railway tracks[30]. The population is growing, and as a result, rail traffic is growing quickly. Numerous electromechanical devices are affected by an increase in rail traffic. By allowing the generator to operate to full load before connecting the load, a delay circuit helps safeguard the appliances as well as the generating set[31]. On the other hand, the power indicator lowers power costs because it uses less energy when running on the public power supply[32] by providing the operator with both visual and aural signals when public power is restored[33-35].

The entire railway infrastructure, including its communication systems, such as walkie-talkies or other devices, has been rapidly evolving over the past 20 years due to the increasing demand for railway services. Konkan Railway uses infrared sensors(IR) with opposed collision devices (ACD) in their collision avoidance systems on the same track[1]. The ACD framework was installed statically. As a result, it is discovered to be ineffectual, yet it turned out to be intuitive. This uses satellites for communication after the usage of geographical sensors. However, the system is also more expensive and intricate. Preventing communication breakdowns and offering an effective means of preventing train collisions are the main objectives of this project[2,3].

Konkan Railways have designed and implemented an opposing Collision System within the current framework. The system was eventually retired because it was unable to receive meaningful active inputs from the current railway signal system and lacked two-way communication capabilities between the trains and the control centres or stops[36]. The ACD system has been retired because it was proven to be useless due to its lack of two-way communication capacity between trains and management centres or stations, as well as its failure to take into account certain active inputs by the current railway sign system. Subsequent geographic sensors that communicate via satellites have also been used[37-40]. But putting the system into place is really difficult. As has been observed in the past, human error or negligence could lead to serious catastrophes under the current system[41]. There was a brief communication gap, serious train damage, and numerous injuries and fatalities. It is ineffective to use manual labour in addition to collision prevention[42].

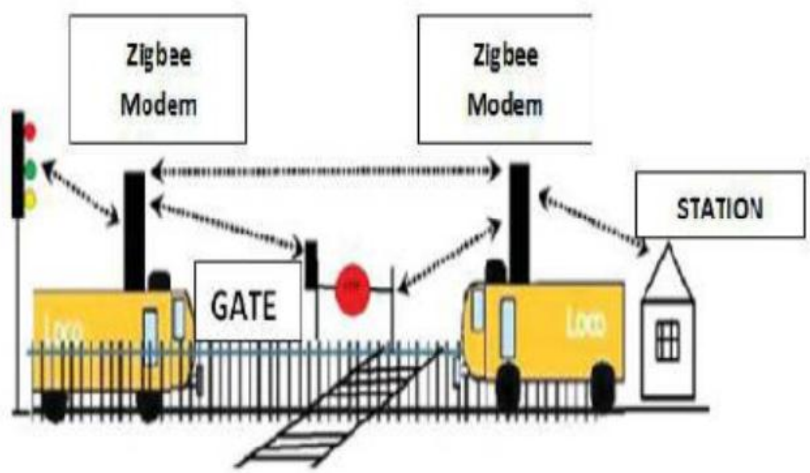

Figure 1- Exiting Railway gate System

Railways are essential conduits for communication and trade in the dynamic world of contemporary transportation. It is not only vital but also a top priority to guarantee the effective and safe functioning of trains throughout this vast network. To meet this pressing requirement, Wireless Train Collision Avoidance System(WTCAS), which is based on wireless transceiver technology, appears as a game-changing solution. This novel technology, which takes its cues from the platooning idea, promises to completely transform the environment of railway operations while also reducing the likelihood of train crashes[43,44].

The railway sector, which is known for its size and efficiency, has long looked for ways to improve security and lower the risk of mishaps. In this endeavour, the WTCAS marks a paradigm change. This system does not only rely on infrastructure-based technologies or human intervention, in contrast to standard train control systems. Rather, it makes use of wireless communication's ability to build a responsive and dynamic ecosystem among trains sharing a single track[45].

Trains are arranged in a hierarchical structure with a leader and followers under the WTCAS framework. As an orchestrator, the leader train is in charge of sending vital information to the other follower trains. This data includes current information on train speed, direction changes, and distance from possible impediments. Most importantly, because of the fast data transfer speeds of the wireless transceivers, this information exchange takes place instantly. Consequently, a coherent and flexible network is established, enabling smooth coordination between trains—a process known as Vehicle-to-Vehicle (V2V) communication[46,47].

Through the removal of traditional control systems' limitations and the adoption of wireless technology, the WTCAS represents a new era in railway efficiency and safety. This investigation delves into the underlying theories of this innovative system, the complexities of its operation, and its ability to establish a previously unheard-of level of safety and dependability in railway travel. In addition to ensuring the safety of travellers and the authenticity of cargo, the upcoming journey is expected to clear the path for a time when trains will run on future railways with unmatched security and precision.

II. LITERATURE SURVEY

A system proposed by Mahesh et al(2016), the OAK-based train collision avoidance system guarantees passenger safety by paving the path for the detection of both static and moving objects. This system can identify things in the track because of its dynamic nature. It provides a strong, safe, and effective communication channel to stop collisions. These days, maintaining and monitoring a track manually is not only incredibly difficult, but also impractical. This essay guarantees current technology in an economical manner.

In inclement weather, the collision avoidance systems proposed by Rohile et al. (2022) are extremely helpful. A system for automatically preventing train crashes and mishaps brought on by crack formation has been created, tested, and simulated. It successfully accomplishes the goals by utilising the ZIGBEE communication mechanism in conjunction with the advanced features of the PIC16F877 micro controller. It is appropriate for many aspects of uninterrupted service on railways. The primary benefits of this system are its silent functions, which include life-saving capabilities, accident prevention, and communicative electronic systems.

From the explanation and facts provided above, it is clear that this system is very dependable, efficient, and cost-effective in areas with large traffic, suburban areas, and rail routes with higher frequency of service. It is more cost-effective than the conventional railway crossing gates system in the aforementioned locations since it eliminates the need for some auxiliary structures and attendant salaries.

Wireless sensor networks are used in Rajkumar et al. (2017)'s suggested method to address the issues. Every train will function as a WSN node, updating its position data via a linked GPS unit, sending the same data back to the server, and using the WSN node to update the database. Included with the suggested solution is a mobile control room on an Android platform. Therefore, Android devices can display all of the information about the nearest trains using the internet or wireless transmission. For rail personnel, the proposed system might be especially helpful in recognising close trains, which would allow them to work more comfortably.

Garcia et al.(2022), focuses on the real-time features of train collision prevention utilising wireless communication. The study employs simulations and case studies to show how effective NRF24L01 transceivers are at ensuring reliable and timely communication between trains.The 2019 review paper by Chen et al. offers insights into new technologies that can be used to improve railway safety. It emphasises the critical role that wireless communication—which includes the usage of NRF24L01 modules—is expected to play in the development of the next wave of railway security systems.

III. METHODOLOGY

This project's technique is based on a methodical approach that gathers pertinent information through an extensive literature research. The Wireless Train Collision Avoidance System (WTCAS) will be designed and developed, with an emphasis on the integration of wireless transceivers, real-time communication protocols, and collision avoidance algorithms. To assess system performance and safety, the project will comprise modelling, thorough testing, and hardware setup.

Evaluations of the system's viability will be carried out to ascertain its scalability and interoperability with the current railway network. Validating the system's efficacy, safety upgrades, and operational efficiency gains will be done through data collecting and analysis. The project will conclude with comprehensive reporting and documentation of the whole development process, conclusions, and suggestions for additional study and application.

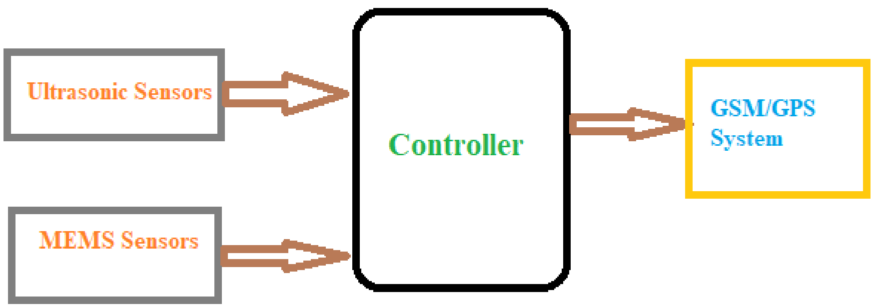

Figure 2- Proposed system.

Figure 2 shows the proposed system. Because the controller has boosted variable capacitors to adjust the current as needed, it is coupled to a GSM system that runs on a 3 volt power source. When an ultrasonic sensor uses sound waves to detect objects in the track, it is monitoring those objects. The waves that the emitter sends, which return to the receiver after bouncing off an object. Subsequently, signals are sent and received between sections using the Ultrasonic Module. When an ultrasonic sensor detects any object on the track, the RF receives a signal from the train section interface through µc.SMS messages are sent to controller stations, drivers, and guards using GSM technology. The controller/microcontroller in this prototype-based system works in tandem with the sensor to detect objects in the track before two feet. as soon as the sensor picks up. The sensational threshold between controllable and unmanageable objects is present in that object.

IV. RESULTS AND DISCUSSION

Train collisions remain a significant safety concern in railway operations. To mitigate this risk, train collision avoidance systems (TCAS) have been developed to enhance the safety and efficiency of train operations. This review examines the recent advancements in TCAS with wireless communication, evaluating their performance, benefits, and limitations.

TCAS with wireless communication typically consists of onboard units installed on trains and wayside units located along the track. Onboard units communicate with each other and with the wayside units using wireless technologies such as GSM-R, LTE-R, or Wi-Fi NRF2401. The system monitors train positions, speeds, and braking distances, and provides alerts to train operators in case of potential collisions.

Studies have shown that TCAS with wireless communication can significantly reduce the risk of train collisions. By providing real-time information on train movements and potential conflicts, the system enables train operators to take timely action to avoid accidents. The system's effectiveness has been demonstrated through simulations, field trials, and operational deployments.

To prevent an imminent collision, the system quickly provides alert signals along with control commands. By carrying out these orders, the trains are securely stopped well ahead of any possible collision, guaranteeing that a safe distance is kept from the danger area.

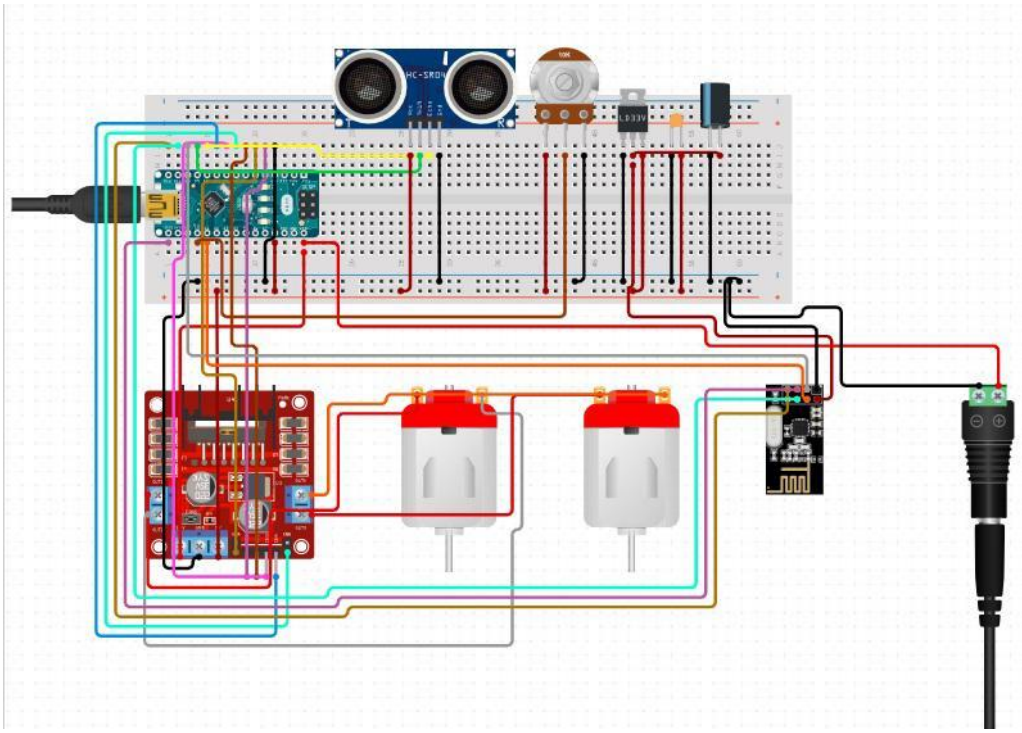

Figure 3- Main Train Module

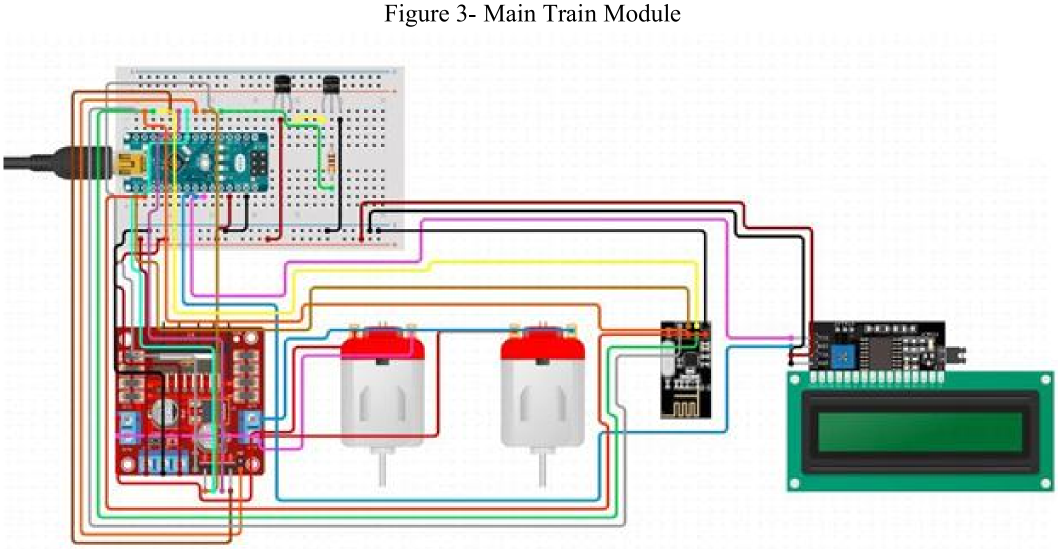

Figure 4- Train 2 Module

Figure 3 and Figure 4 shows the main train module i.e. transmitter and train 2 Module i.e. receiver respectively. Although the controller has boosted variable capacitors to adjust the current as needed, it is coupled to a GSM system that runs on a 3 volt power source. When an ultrasonic sensor employs sound waves to detect items in the track, it is monitoring those objects. The waves that the emitter sends, which return to the receiver after bouncing off an object. Subsequently, signals are sent and received between sections using the Ultrasonic Module. When an ultrasonic sensor detects any object on the track, the RF receives a signal from the train section interface through µc.SMS messages are sent to controller stations, drivers, and guards using GSM/ NRF2401 technology. The controller/microcontroller in this prototype-based system works in tandem with the sensor to detect objects in the track before two feet. as soon as the sensor finds. The sensational threshold between controllable and unmanageable objects is present in that object. The item won't give the information to anyone else if it is a managed object. Otherwise, if the object is unmanageable, it will notify the driver, the guard, the controller station, and the driver about the specific track status as soon as it is identified via the alarm system and message forwarding to the driver's mobile device.

The sensor notices the obstruction in the track when a train approaches a lane. In this application, the microcontroller serves as a translator between the end application and the hand gesture. An obstacle can be categorised as manageable or unmanageable based on how mobile it is. The driver, the guard, and the control room receive the alert data if the object is unmanageable; otherwise, it may be detected on its own (leaf, paper, etc.). The regulator requires a 3V power source to operate, and the Android handheld devices receive the detected information via the GSM/ NRF2401 Module. In the event of an emergency, the control room staff can quickly pinpoint the train's location using the GPS/NRF2401 module, enabling reliable and efficient rescue operations. Using the MEMS technology included in this micro kit, aberrant train travelling might be detected. If this happens, a buzzer is triggered, allowing the aberrant driving to be stopped. The conventional system itself allows for the train's activation. A buzzer sound will indicate irregular running behaviour. For Communication we are using NRF2401.

V. CONCLUSION

The project's intended outcome is that the use of wireless transceivers in the deployment of the Wireless Train Collision Avoidance System (WTCAS) will significantly improve railway safety by lowering the likelihood of train crashes. The WTCAS will show its effectiveness in reducing accidents and optimising train operations, which will enhance operational efficiency, enabling real-time communication and coordinated control. The project will verify the system's adaptability and scalability, proving that it is a workable option for updating the current railway infrastructure and facilitating future growth. The project's results will also highlight the possibilities of wireless communication technology to transform railway safety, opening up new avenues for study and advancement in the areas of collision avoidance and railway automation.

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