LoRa Railway Safety System for Accident Prevention

Sukhdeep Kaur, Ashpinder Kaur Kabir, Harmanpreet Kaur
Department of computer science and Engineering, CGC-College of Engineering, landran Mohali, Punjab

***Abstract*: IoT applications play an indispensable role in transforming traditional systems into highly interconnected and intelligent networks. LoRa is one such IoT application using which we can overcome the serious problem of increased railway accident by detecting obstacles in its path using pyro-electric sensors with integrated LoRa module. If any obstacle is detected the signals are sent to server using the long-range communication and after all the data processing and recognizing the genuineness of the hinderance the alert mechanism is automated, helping to perform shift actions to avert accidents.**

***Index Terms*—LoRa, IoT (internet of things), pyroelectric ssensors, obstacle detection.**

1.INTRODUCTION

On 19th, October a catastrophic railway incident in Amritsar, Punjab, claimed the lives of at least sixty-two individuals and left approximately 200 more injured [1]. This tragedy occurred when two passenger trains collided with a crowd standing on track to witness Dussehra festivities. This unfortunate event highlighted the urgent need for railway safety measures to prevent such devastating accidents.

Despite advances in railway technology, ensuring the safety for passengers and track-side observers remains a significant challenge. With million dependents on railway for daily transportation, even minor lapses in safety protocol can result in severe consequences. In light of this challenges, this research endeavours to presents LoRa (LONG RANGE) based comprehensive solution triggered at enhancing the safety framework of railway systems.

2.LORA OVERVIEW

LORA (Long Range) is a wireless communication protocol that operates within sub-GHz frequency bands, offering low-power and long-range data transmission capabilities. By employing Chirp Spread Spectrum (CSS) modulation, LORA ensures robust signal propagation, high resistance to interference, and minimal data loss, making it suitable for deployment in environments with significant physical obstructions or challenging terrains [2]. Its energy-efficient operation allows devices to function over extended periods, making it ideal for continuous monitoring applications.

In contrast to Bluetooth, which primarily operates in the 2.4 GHz frequency band and is restricted to short-range communication of approximately 100 meters, LoRa supports data transmission across several kilometres [2]. This wide coverage capability is particularly beneficial for railway systems, where reliable communication across remote and expansive networks is essential. Furthermore, LoRa's point-to-multipoint connectivity facilitates scalability, enabling efficient integration of large sensor networks without requiring complex infrastructure.

With its high link budget and resilience against environmental interference, LoRa meets the requirements for real-time obstacle detection and monitoring in railway safety applications. Its low-bandwidth communication model ensures energy-efficient data transmission while maintaining stable and secure connections across railway networks, effectively enhancing operational performance and mitigating safety risks.

3.EDGE OF LORA OVER OTHERS

- Unlike, prevailing technologies like Bluetooth the perk of using LoRa is that it covers wide area making it fit for large-scale and remote network.
- In contrast to the cellular communication which is cost-intensive, it is cheap and requires minimal operational cost [3].
- It also offers higher scalability over traditional technology like Bluetooth. For instance, using Bluetooth we can only connect to one device like cell phone with headsets. While, we can have multipoint connection using LoRa like we can connect multiple sensors at a particular instance of time.
- LoRa's robustness against interference and its ability to operate reliably in harsh environmental conditions give it a distinct advantage over other communication technologies [4]. It happens by amplifying the signals to transmitted over long range to reduce noise in it.

4.LORA FOR IOT EFFICIENCY

The Key difference between the old "Internet" and the "Internet of Things" (IoT) lies in the limited resources that IoT devices are designed to operate with. These devices typically feature reduced memory, processing capacity,

bandwidth, and energy availability [5]. Such constraints are primarily due to the fact that most IoT devices are powered by batteries, making energy efficiency a critical factor for extending their operational life. Traditional communication technologies, such as cellular networks or Wi-Fi, are often impractical for IoT applications due to their high energy consumption and limited scalability. To overcome these limitations, Low-Power Wide Area Networks (LPWAN) have emerged as a specialized class of communication technologies tailored for IoT needs. These networks are designed to provide extensive coverage across large geographical areas using base stations, while optimizing parameters such as transmission rate, power usage, and duty cycles [2]. This ensures that devices connected to the network consume minimal energy. Among LPWAN protocols, LORA (Long Range) has gained prominence due to its suitability for scenarios where devices operate on constrained energy sources, such as batteries, and require only minimal data transmission. LORA's unique characteristics, including its ability to cover wide areas with low energy demands, make it ideal for a range of applications, including smart infrastructure monitoring (e.g., environmental sensing, utility metering, and health monitoring) and industrial automation.

A. State of Art

The rapid advancements in communication technologies and the increasing adoption of the Internet of Things (IoT) have driven the development of innovative solutions for railway safety systems. There are various prevailing railway safety systems and one of them is GSM-R.

GSM-R:

- GSM-R stands for Global System for Mobile Communication- Railway. It is an international wireless communication standard for railway communication and application and is the part of European Rail Traffic Management System (ERTMS) [7].
- GSM-R uses dedicated base stations for the communication and these base stations are installed after every 7-8 Km and in the places where base station cannot be installed such as tunnel or any narrow track, directional antenna or Leaky cables are used throughout to cover entire rail track [6].
- GSM-R operates in specific frequency bands adjacent to standard GSM frequencies. It uses uplink frequencies (from train to base station) between 907.8–909.4MHz and downlink frequencies (from base station to train) between 952.8–954.4 MHz [8]. The use of this specific range of frequency band ensures minimal interference with public GSM networks.
- GSM-R supports both voice and data communication between train drivers, railway staff etc.

B. GSM-R Features:

GSM-R offers various call features to ensure efficient and safe communication. The first and the foremost is Point-to-Point Call [7], it enables the direct communication between two users. Secondly, Voice Group Call System (VGCS) allows group communication think of analogous example of walkie-talkies, where only one person can speak at a time. Third call feature includes Voice Broadcast System (VBS) [7], a one-way communication feature where only initiator can speak, while other acts as listeners. Last but not the least include call features like Railway Emergency Call and Shunting Emergency Call, which are high priority VGCS used during the time of any emergency or critical situation only.

More advanced features of GSM-R include Functional Addressing [8], allowing calls to be made on the basis of role like captain of particular train etc. Location Dependent Addressing, ensures calls are routed to nearby train controller based on train's geographic position.

D. GSM-R Drawbacks:

- The major loophole of adopting GSM-R railway safety system is that it requires huge implementation and maintenance cost of Base stations.
- It is also difficult to handle hand-off as train travels at high speed.
- Since GSM-R is 2G based technology so it has restricted data transmission capabilities, making it less suitable for high-speed data transfer.

To address the shortcomings of GSM-R and meet the demands of modern railway system the adoption of LoRa technology presents a promising solution.

LoRa is Low Area Wide Area Network technology offering various advantages and covering up the limitations of GSM-R technology by providing

scalable, efficient and long-range communication. Unlike GSM-R, which need more funds for its installation LoRa requires less setup cost. Additionally, LoRa supports seamless hand-off and data transmission, even when trains travel at high speeds, addressing one of the critical challenges faced by GSM-R. With its capability to handle modern IoT applications. Lora offers low power consumptions as compared to the gsm and other traditional methods of railway safety moreover it provides more flexibility by allowing more addition of sensors over long distance which could be ideal for the large railway tracks.
LoRa enables real-time monitoring, obstacle detection, and efficient data sharing, providing an innovative and sustainable solution for improving railway safety.

Operational Flow of LoRa Based Safety Mechanism:
To implement an effective railway safety mechanism, the operational workflow of LoRa mechanism is designed to relish the capabilities of long-range communication. Let us understand every stage of the workflow diagram in minute detail.

The mechanism is initiated by deploying sensors particularly pyro-electric sensors along the railway track, which monitors the potential obstacles or hazards. This information is passed on to further stages of the proposed solution and the action is taken accordingly.

Below is the visual representation of operational flow of the LoRa Based Railway safety mechanism:

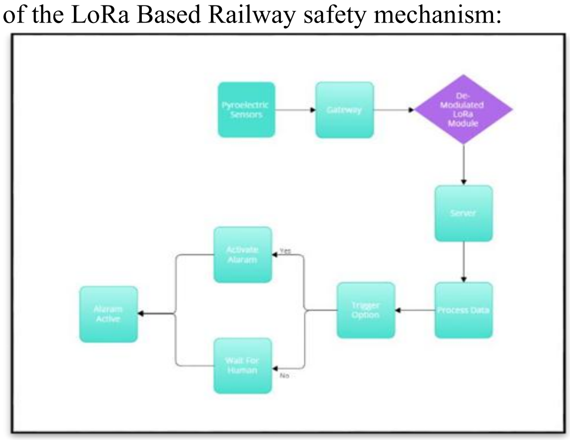


Fig 1.1 Operational flow of LoRa

Let us understand each and every stage of above visual representation in detail:

A. Pyro-electric sensors:

- Function: The pyro-electric sensors detect heat signals from the object on or near the railway track.
- Interaction: These sensors are deployed along the railway track at regular interval. In case, any object is detected, the sensors generate an electrical signal.
- Contribution: These sensors play a vital role for identifying obstacles. Without them, the system would be unable to detect hazards on the track.

B. LoRa Based Communication Module:

- Function: The system uses LoRa (Long Range) LRWAN, wireless technology for communication.
- Interaction: The LoRa communication module receives the signal from the sensors and send it to the gateway. It allows the mechanism to operate over long distance as compared to other wireless technology like Bluetooth while consuming minimal power.

Contribution: This module provides long-range, low-power communication for transmitting data efficiently over large railway network. In absence of this module, we would have to use wires which would be funds consuming and less efficient.

C. Gateway:

- Function: The gateway receives the modulated signals from the LoRa modulated sensors and the function of gateway is to demodulate them for further processing.
- Interaction: It acts as a broker between the sensor's topology and the central server.
- Contribution: The gateway plays an indispensable role to interpret the data collected by the sensors, allowing the server to process it. If it would not be there, then there would be no communication between the sensors and the server.

D. Central Server:

- Function: The central server processes the data received from the gateway, it analyses whether an object poses a risk or not using various machine learning algorithm and various python libraries like OpenCV.
- Interaction: Based on the above analysis, it decides whether an alert need to triggered or not.
- Contribution: The server is crucial for decision making and real time analysis. It makes sure that only valid threats activate trigger mechanism, reducing false alerts and enhancing system reliability.

E. Trigger Mechanism:

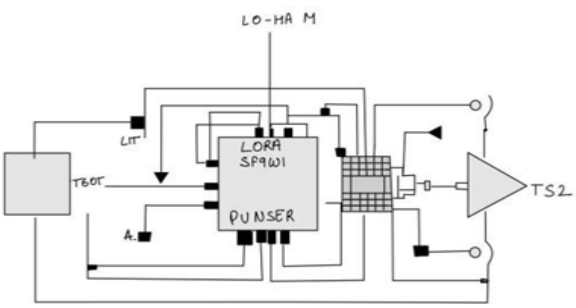
- Function: If the server detects the obstacle, it activates the trigger mechanism. The trigger mechanism includes the activation of alarm on-site where the obstacle was detected and the train pilot is also informed by the scenario.

- Interaction: It is controlled by server. Upon detecting any hurdle, it initiates the alarm system and warns the approaching train.
- Contribution: Without it, the system would be unable to take any preventive action in response to an identified threat.

This was the overall workflow of the opting LoRa as the railway safety system mechanism.

5.CIRCUIT DIAGRAM

This is a circuit diagram that represents the prototype of the loRa module.



- Lora module (SFW1): It is an ideal prototype that wirelessly communicates for IOT application.

Here, SF9 affects the range and data rate. W1 is the bandwidth. It acts as a main unit of communication to send or receive data through wireless network.

- PUNSER: It handles serial communicate with Lora module. punser is a microcontroller that deals with input/output logics, timing and control functions. It is basically a processor that is used to process data from sensors
- LO-HAM: It is a control line of modulation system. It is used to regulate high and low signal levels of the communication. It is referred as control switch.
- LIT: It is a LED when device is sending data. It will glow light when the signals are sent and data is transferred and acts as an indicator.
- T6oT: It is an external input module or sensor unit. It sends data or trigger to the punser for further processing.
- A.: A(dot) It is a control line of modulation system. It is used to regulate high and low signal levels of the communication.
- TS2: It is a signal amplifier. It is used to send data outward wirelessly. It also gets activated if any danger get detected by the system.

The signal lines represent the flow of data between sensors, processor and other units.

WORKING:
Sensors such as T6oT and A. sends signals to punser , these sensors detects the hazards such as obstructions, excessive vibration on the track then the punser collects the data and process these signals as input. It sends data to LoRA SD9W1 module. If any abnormal condition is detected the Then the LoRa module transmits this data to the remote device wirelessly using LO-HAM to the near most train control centre. The LIT line light up to indicates transmission. This process take place in loop after reset the system it starts to continue the monitoring in the real time Then the LO-HAM adjusts the power level and TS2 point serve as the final output.[9]

6.CHALLENGES

Network connectivity in remote area can be a challenge for this wireless technology.
Bad weather conditions such as snow, dense fog and heavy storm, the performance of the sensors may get affected and leading to inaccurate detection or error.
Regular maintenance is required such as battery replacements must take place regularly. If batteries run out the sensors fails to transmit the data that will compromise the effectiveness of the system.
Deployment at a large scale for such a large railway network is quite challenging.
The lora technology sometimes operated in the unlicensed frequencies which can limit the transmission power and overall performance.
Large scale data transmission can be difficult with certain low frequencies of lora.
Scalability and management at a wider level could be another challenge of lora.
The performance of lora technology can be hinder by several other factors like dense vegetation areas, mountainous areas, modernised urban structure.

7.CONCLUSION

Lora is wireless technology with low cost and low range connectivity. It is a cost-effective option for railway safety system. This technique is energy efficient that make it better over other traditional railway communication modes. Lora covers large area with low energy demands.
With proper implementation of power source and infrastructure, it is a promising technology used to

enhance the railway safety at prominent levels. It provides the real time alerts for the railway safety measures. This is technology could be considered as more efficient with low power as compared to gsm and other techniques.

It also ensures to improve safety in the unmanned crossing lines in the rural areas.

Lora can play a significant role in the railway safety and communication with a wide range of industries.

REFERENCE

[1] “Amritsar Train Accident Death Toll Rises To 62". *NDTV*. 21 October 2018.

[2] "What are LoRa and LoRaWAN?" by The Things Network.

[3] "DyLoRa: Towards Energy Efficient Dynamic LoRa Transmission Control" - INFOCOM 2020.

[4] "Improving the Reliability of Long-Range Communication Against Interference" - MDPI.

[5] "A Survey of IoT: Enabling Technologies and Applications" Overview of IoT constraints and resources

[6] “The UIC emphasizes GSM-R's role as a secure communication technology enhancing railway safety and efficiency”- UIC

[7] “Willtek highlights GSM-R's role as a communication standard enhancing railway systems and IoT integration” Willtek

[8] “GSM-R is a railway communication system ensuring secure and efficient operations”- Wikipedia.

[9] LoRa WAN 1.0.3 regional parameter TR007 developing LORA devices 1.0, technical recommendation.

[10] lora based railway signalling system by Mr. M Vignesh Kumar, Mr. V. Dhanraj, S. shrinath, M. kesavakumar, G. Sabari Karthik.