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sRailer: A Secure Automated Indian Railway Track Switching System towards Smart Transportation

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Abstract: The global urban landscape is in the midst of a significant shift. The cities around us are getting transformed and becoming more connected and digitalized. Following the cutting-edge technology, the transport system is also transforming. Railway transport has seen a lot of mishaps for decades. Increasing accidents in the Railway sectors due to mismanagement of train tracks sparks the development and deployment of automatic train track switching mechanisms, reducing the accidents to a minimum.

This paper presents a technology that uses Geo Positioning Satellite (GPS) and Radio Frequency (RF) communication to bring forward a mechanism that could automate the present manual system of track switching. The major advantage of our technology is that it increases the efficiency of the present operation. We also use the Advanced Encryption System (AES) algorithm to encrypt the communication between the RF channel nodes. Based on the experimental analysis, we demonstrate how this technology is a cost-effective solution to the present problem.

Keywords: Smart City, Smart Transportation, Railway Track Switching, Secure IoT, Secure Cyber-physical Systems, Interlocking

I. INTRODUCTION

Smart cities have become a concept to develop the traditional network and services and making them more flexible, efficient, and sustainable using information, digital, wireless communication technologies. Transportation is a major component of emerging smart cities and contributes largely to making the cities smart and efficient. With the constant development in the traditional transport system, various communication and navigation systems are being used in vehicles [1].

Since the Railways' advent into transportation modes, it has always been the most preferred way of public transportation. Even it is considered one of the fastest transportation modes satisfying the economic and ecological criteria. Many rail accidents cases have discouraged the people from opting for this transportation, causing massive losses to the transport departments. Therefore, it is necessary to have regular updates in technology for the betterment of this transportation system. Most of the accidents that are caused are due to wrong track alignments of the trains.

The accidents caused due to this scenario are hugely catastrophic. Earlier, the track alignments are performed using the electromechanical relays [2]. Recently, there have been many upgradations to this operation, some of which are Route Relay Interlocking and Solid-State Interlocking. Considering the Indian Railways, the Railway body uses a cascaded system to operate the track switching.

It uses the Route Relay Interlocking and Solid-State Interlocking mechanism to control the operation [3]. The mechanism is as sophisticated as it is, but it requires manual input to track change. As we all know, manual inputs can produce errors, and these small errors can cause disasters.

Various methods have been used for real-time tracking, but they are not that efficient in performance. GPS based location detection and data transmission using radio frequency improve the current signalling system [4]. In this paper, the proposed system automates the Railway's current working by eliminating the manual input, which is slow, error-prone, and can be unsafe many times. The application of the interlocking system in Railways is shown in Figure 1.

The rest of the paper is organised in following sections. Section II describes the Novel Contribution. Literature Reading is presented in Section III. Section IV includes Proposed System Structure and Design is presented. The Working Methodology is presented in Section V. Section VI includes the Simulations and Results. Section VII includes Conclusion and Future Scope.

Fig. 1 Interlocking Panel in Control Room [15]

II. NOVEL CONTRIBUTIONS OF THE CURRENT PAPER

Automation has been an integral part of the development in various sectors. It has been continuously developing different divisions of railways [5]. Interlocking is an important part of the railways signalling system. It is a combination of signal devices through tracks like junctions, which prevents conflicting movements. These crossings help in changing the track to change the train's route. This method includes manual inputting at some level, which in many cases, causes an error. The proposed system will completely automate the running system, which will increase the efficiency of the same. GPS communication will be used to gather the current location data. The next station code is found using a defined algorithm. With the help of radiofrequency communications, the data will be transmitted from the trains to the track changing cabins to perform the track change operation. The main part of this work is a novel approach to an AES hardware implementation.

III.RELATED EXISTING WORKS

The most extensive systems in the 2000s were mechanical interlocking systems. These systems are accustomed to coordinating the levers' positions by controlling the points with the signals governing that section of track and connected branches, loops, or sidings. The maintenance of RRI systems is costly and complex. So, it was needed to develop a better system that would reduce the number of relays and maintenance. When built using electronics replacing traditional mechanical levers and electromechanical relays, an Interlocking System is called the Solid-State Interlocking (SSI) system. The station yard consists of the control table, which provides the trains' possible movements within the yard, which is further stored as lookup tables in software designed for the same [3].

There has been much tremendous work performed in the field of 'Interlocking' [6]. A microprocessor-based interlocking control is introduced, which uses error detection methodology [7]. A computerized interlocking system is discussed where again, a microprocessor-based design is implemented to control the interlocking mechanism [8]. Though all these works have provided many technical upgradations to the present system, they still require manual input to operate. Post the input; these works improve further operation in accuracy and reliability. Concerning the automation of the train track switching mechanism, technologies like IR detection is used to detect the presence of train and switch tracks automatically [9]. Many works have also used RF communication. The use of RFID in automating track switching is also seen in this paper [10]. In this method, RFID tags are spread on the tracks, and the train moves according to a given code. When the train approaches the RFID tags, the tags share data, which determines whether the train is on the right track or not. This method's limitations are that using tags in an open environment might damage the circuitry of the tags, which could lead to some potential delay in data transmission or incomplete data transmission. Hence, this system might not detect the correctness of the train's route and detect whether the train is an incorrect route. This might cause a problem in the operation of the other trains. Wireless communication and distributed computing have promoted the development of a vehicle monitoring system. Communication technology, including communication infrastructure, has become more cost-effective and pervasive in the last five to eight years. A lot of work has been done in wireless data collection and communication systems in railways [11]. GPS technology is being used throughout the world to track the movement of locomotives [12]. A patrol system was devised using GPS and RFID technologies for patrolling railway signal devices. GPS and RFID are incorporated into the standardization of operation when a device is opened and checked. Various wireless technologies are used in Railway industries for both communication and signalling purposes. It includes communication between drivers and signallers at any time from any point of the station. The track monitoring system includes a track settlement sensor followed by data acquisition and data processing [13].

IV. PROPOSED NOVEL SYSTEM FOR SECURE AND AUTOMATED TRACK SWITCHING

The vital part of this proposed system is to gather the train's positional data, which in this framework is done using a sensor system. The sensor used is a GPS module. The data gathered from the GPS module is then processed using some predefined algorithms. The communication channels transmit the data from the sensor system to the VDU cabins to perform adequate tasks. Based on the data that they receive; the VDU cabins actuate the relays present near the tracks to perform the adequate operation. The proposed framework is presented in Figure 2.

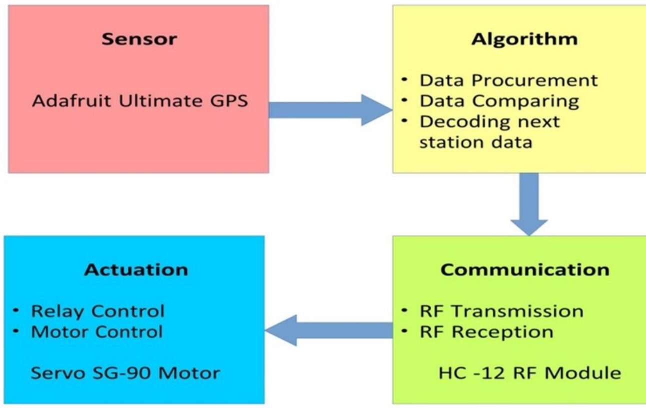

Fig. 2 The Proposed Novel System for Secure and Automated Track Switching

The System structure is divided into four sections. A sensor system for data acquisition, Processing of gathered data through the various algorithm, Transmitting the processed data to the receiving section, and Control action of the actuator through the receiving signal. The transmitter on the train includes data extraction, Data processing, and Data transmission. The entire process occurs in the locomotive itself. The data collection and actuation part are included in the receiver near the cabin. The data receiving section is connected to the cabin, consist of a VDU display, through which the present interlocking system is continued. The proposed approach is demonstrated through Figure 3, and it is shown for only a single line system. In Railway system, there is two parallel tracks running to each other "up track" and " down-track." While entering the station, the train travels through either up track or down track. After that, through crossovers, it changes track to different platforms. So, in our system, the receiver will be kept near the up track or down track.

A. Transmitter on the Train

The transmitter section includes a GPS module, a Radio Frequency transmitter module, a microcontroller, and a power supply unit. The setup is mounted on the locomotive front upper part inside a hard plastic/wooden casing. It receives power supply from the supply unit placed inside the engine. Figure 4shows the design of the transmitter module.

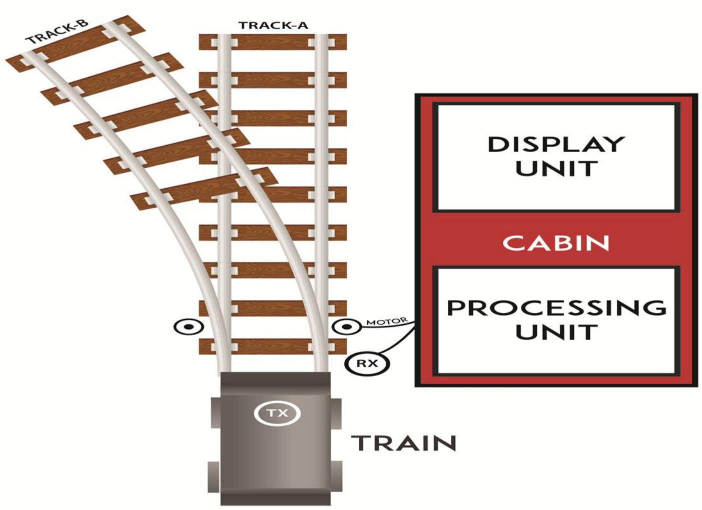

Fig. 3 Illustration of Railway Track Switching

B. Receiver Near the Track

The receiver section includes the RF receiver module and microcontroller. The setup is placed near the station entrance, at a certain distance from the track change point. It collects the data sent from the transmitter module through the transceiver. The data thus received is decrypted using a decryption algorithm running in the controller. After decryption, the data is used to decide which track is to be selected. It is transferred to the control panel cabin, and the relay near the track change point is actuated through the existing technique. The output actuates the motor that controls the track switch. Figure 5 shows the design of a receiver module.

C. Usage of AES algorithm

As mentioned earlier, the proposed technology is designed to work in an AES encrypted channel. The encryption algorithm is known to be computationally intensive. AES algorithm runs in both the controllers to encrypt and decrypt the data, respectively. It is most efficient in terms of speed, time, throughput, and the avalanche effect. The above process requires a public key. Hence, both the transmitter and the receiver must have the public key to be a part of the communication. This AES algorithm's usage makes sure that communication is completely safe and secure from outside cyber-attacks and RF interferences.

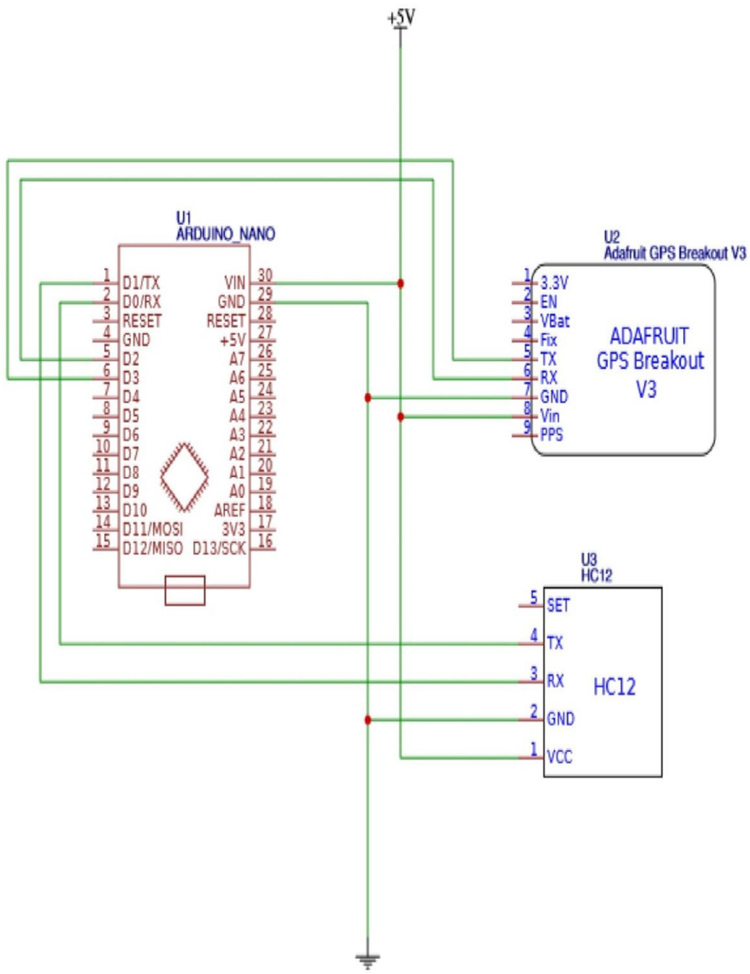

Fig 4. The proposed System level Design of Transmitter

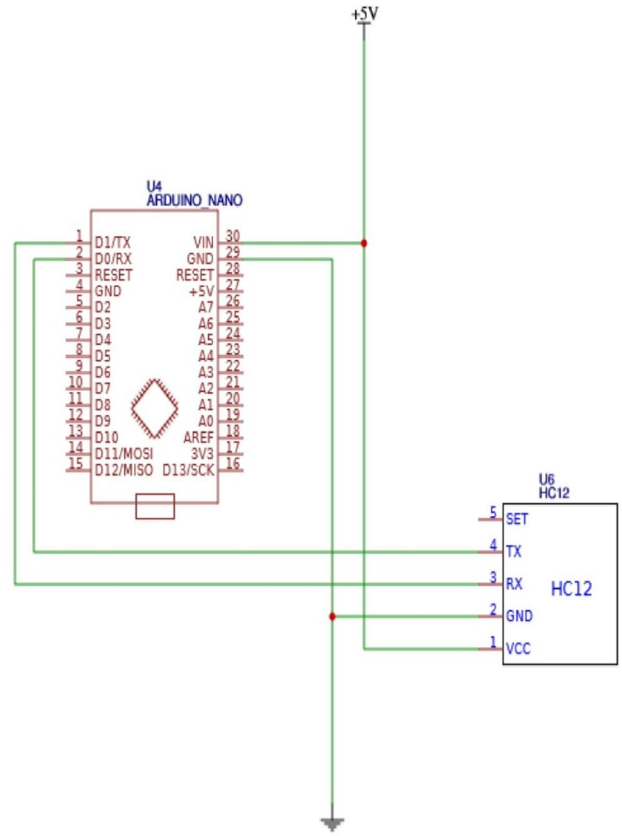

Fig 5. The proposed System level Design of Transmitter

In our proposed system AES algorithm is an excellent selection to be considered because from our system's point of view, where we are dealing with small data packets, AES has a better performance than other standards encryption algorithms since it has not any weak security-related issue, consumes less processing time to encrypt small byte data packets as compared to DES, 3DES, Blowfish, RC4 standard algorithm, hence reducing the CPU load and also has a far better encryption throughput than others. Though it consumes a little more processing power, it is quite effective for small-sized data packets, and it consumes three times lesser power than other encryption standards for encryption of low byte data. While selecting the encryption key for our AES algorithm, as the power consumption increases with increase in key size, the 128-bit encryption key will be the best selection for us as the AES encryption algorithm with 128 bits is fast enough, power consumption is very less and also from the security perspective the data is very well protected and unbreakable.

V. PROPOSED NOVEL SYSTEM FOR SECURE AND AUTOMATED TRACK SWITCHING

The workflow of the proposed system is shown in Figure 6 and Figure 7. The proposed methodology is based on simple RF communication between two nodes. The two nodes being the transmitter on the train and the receiver in the track switching location. Every train will have a route-specific data map to get the next location data. For example, let us say from Station ABC that there are two diverging routes: station LMN and another to Station XYZ. Train - A goes from Station ABC to Station LMN, and Train - B goes from Station ABC to Station XYZ. When the trains pass through a certain point in Station ABC, the GPS module detects the position, sends the data for processing where the next location is searched and transmitted to the receiver. For Train - A, when Station - ABC is detected, the transmitter will send “LMN” in encrypted form to the receiver, and the track will change to Station - LMN route. For Train - B, when Station - ABC is detected, the transmitter will send “XYZ” in encrypted form to the receiver, and the track will change to Station - XYZ route.

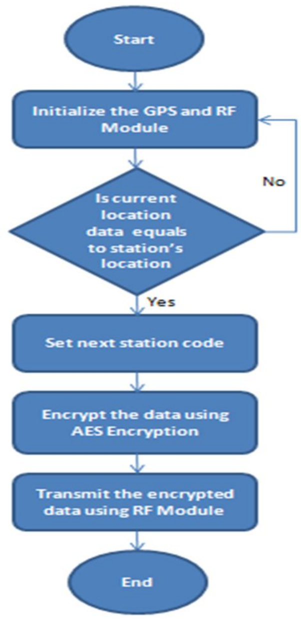

Fig 6. Flowchart of Transmitter

At the receiver end, the data received will be decrypted data, and the next station code will be used to select the track for that specific train. We use the train's latitude and longitude data at a particular location to process the next station. As we know, a change of about 111 km changes 1 degree of latitude/longitude. We are using values up to 2 decimal places. For about 1 km change in distance, there will be a 0.01-degree change in latitude or longitude. And as mentioned before, the HC-12 can have a readable range up to 1 km in the line of sight. With all these specifications, when a train is at a distance of at least 500 m from the track change section, the track change will occur without any problem. Even if we have a super speed train on the track, our technology will not fail to change the track within the required time. Thus, the proposed system is highly accurate and precise.

During data transmission from the transmitter to the receiver, there may be a chance of error caused due to transmission channel noise, distortion, some attenuation problems, and wireless multipath fading. As our system deals with low byte data transmission, there is a little chance of error, and if it exists, then the packet error ratio (PER) is minimal. This effect can be avoided using a simple error detection and correction scheme, i.e., parity bit based forward error correction method.

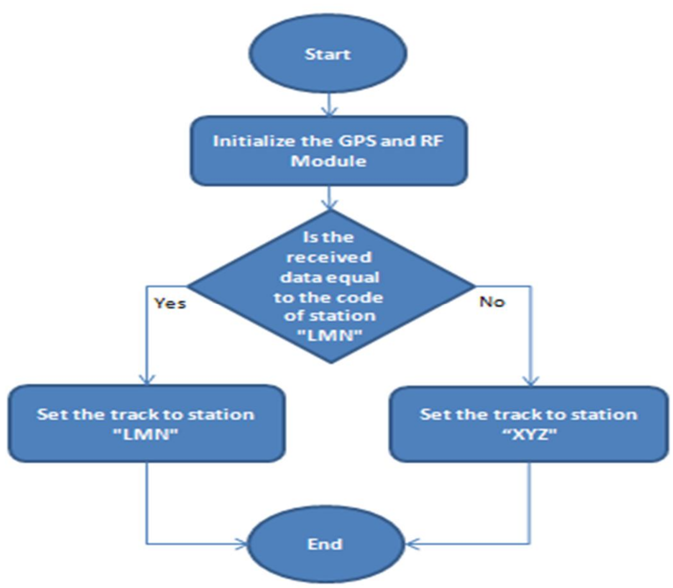

Fig 7. Flowchart of Receiver

VI. EXPERIMENTAL VERIFICATION

The designed model was tested in a simulated environment with a DC motor. In the real-time application, the DC motor will be replaced by the "present Solid-State Interlocking/Route Relay Interlocking mechanism." Our prototype would send actuating signals to the present system to bring about the track switch. We tested the prototype for two cases. Considering the track change section is present in Station - "ABC," and there are two diverging routes to Station - "LMN" and Station - "XYZ," Figure 8 and Figure 9 shows the experimental model of Transmitter and Receiver respectively and Figure 10 shows the output of the receiver terminal.

The components used in the design of the system are as follows:

1) *GPS Module:* The GPS module used here is the Adafruit Ultimate GPS Breakout. It has -165dBm sensitivity, 10Hz updates, 66 Channel, and it draws only 20mA current. The chipset used to build the module is MTK3339, which can track up to 22 satellites on 66 channels. It is compatible with the NMEA 0183 protocol. It also has a built-in antenna. GPS technology allows for the exact coordinates of the locomotive over a certain time span. The HC-12 transceiver module works in a half-duplex wireless serial communication mode with 100 channels within the 433.4-473.0 MHz range capable of transmitting up to 1 km [14].
2) *RF Module:* The RF module used is an HC-12 transceiver. It is a wireless serial port communication module that can transmit and receive data up to 1000m in clear sight. The working frequency is between 433MHz to 473MHz.
3) *Arduino Nano:* Arduino Nano is an open-source development board based on the Atmega328P chip. It consists of 14 digital pins and 6 analog pins, with an input limit voltage between 7 to 20 v. It has a flash memory of 32 KB and a clock frequency of 16MHz.
4) *Power Supply:* A DC voltage is provided to the microcontroller from the power supply unit of the locomotive.

a) Case-1

Train - 1, going from Station - "ABC" to Station - "LMN."

On arriving at the geographical location of Station - "ABC," the transmitter sends the code "LMN" to the receiver, which then sets the track to "LMN" and the DC motors rotates in a clockwise direction to carry out the change.

b) Case-2

Train -2, going from Station - "ABC" to Station - "XYZ."

On arriving at the geographical location of Station - "ABC," the transmitter sends the code "XYZ" to the receiver, which then sets the track to "XYZ" and the DC motor turns in an anti-clockwise direction to carry out the change.

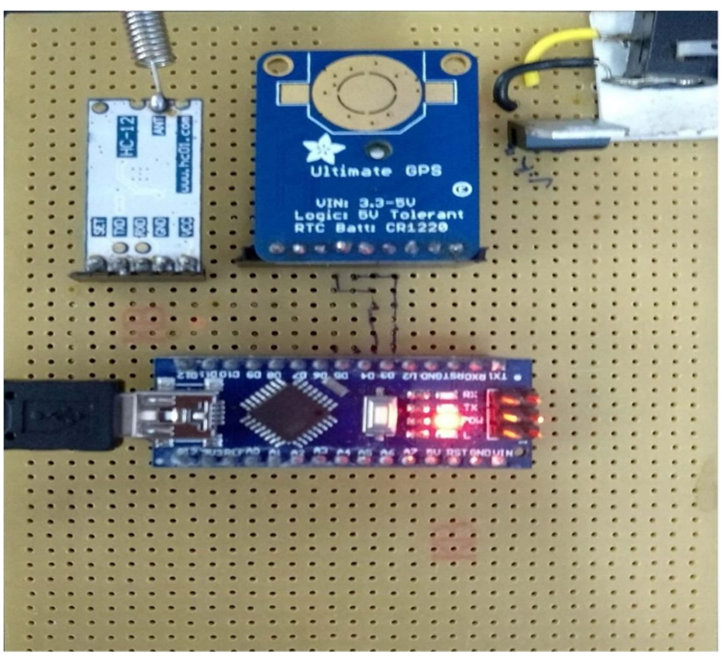

Fig 8. Design of Transmitter

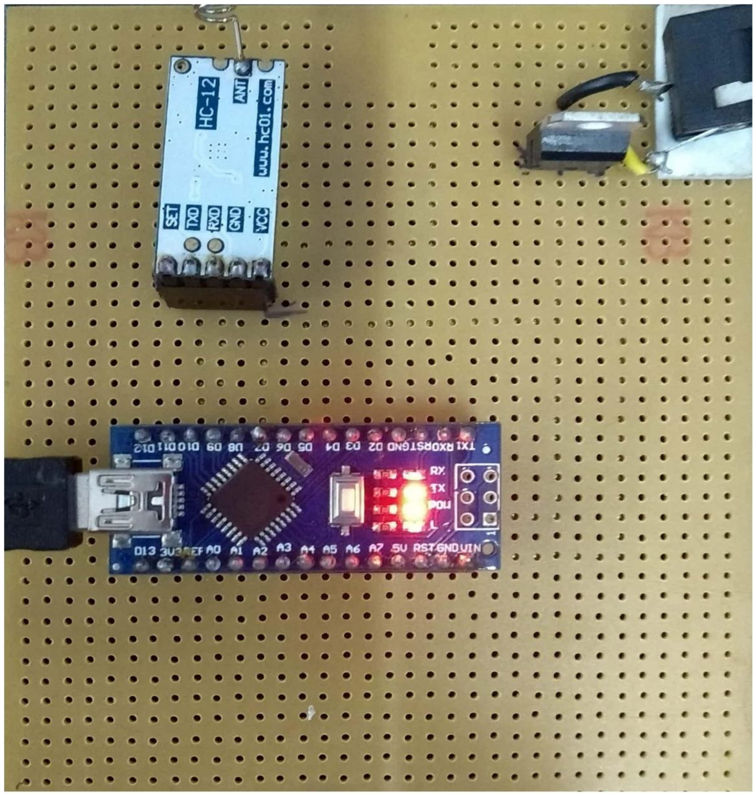

Fig 9. Design of Receiver

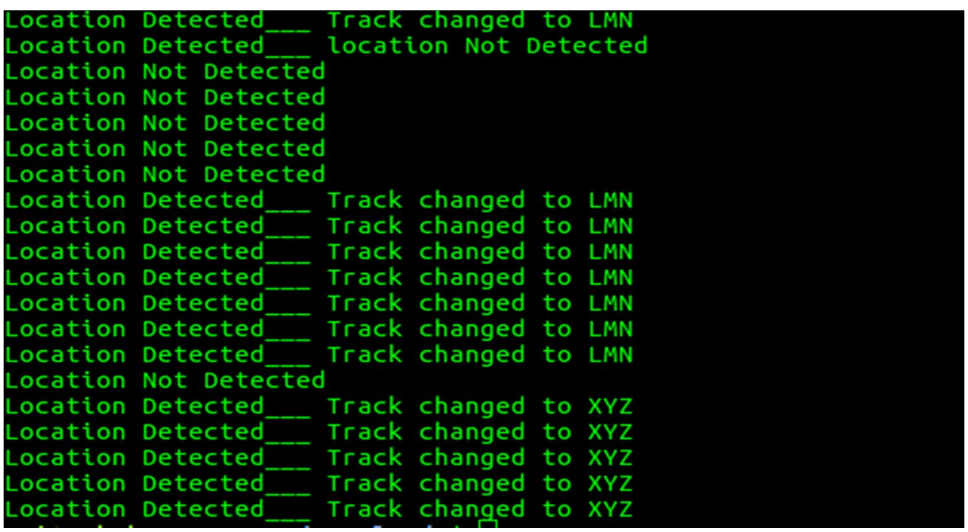

Fig 10. Output on the receiver terminal

VII. CONCLUSION AND FUTURE SCOPE

This paper has presented a prototype to automate the track switching mechanism using GPS and RF communication. The proposed solution shows the enabling technology is a viable, cost-effective solution for accurate operation in real-time. The AES algorithm used is constructive for the operation as it would safeguard the communication between the nodes from any outside cyber-attack, and the communication is encrypted. This prototype would save a lot of lives and infrastructure of the Railways and increase the efficiency of the current interlocking system. In this prototype, we have done the RF data transmission based on the transmitter side by using GPS, where we are taking a particular position, and from that, the next station is inferred. We can implement this concept on the receiver side too. In that way, we will check the incoming train status for track change and checks the platform information status and compares both to set the track for the same.

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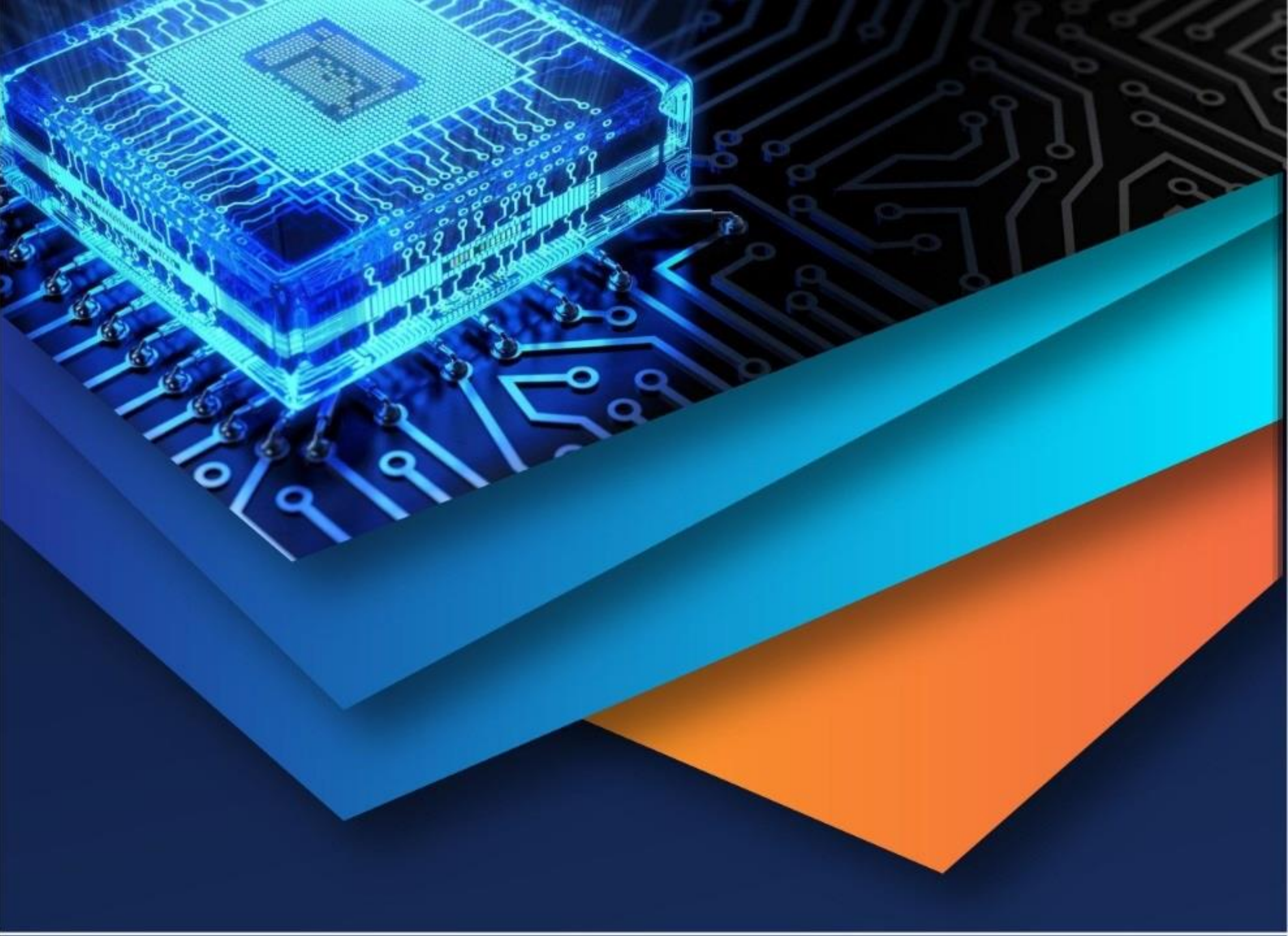

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