Implementaion of ZigBee Based Train Anti-Collision And Level Crossing Protection System for Indian Railways

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Abstract—Implementation of an efficient ZigBee based Train Anti-Collision and Level Crossing Protection System for Railways is being proposed in this paper. The system has four sub modules namely, Train Module, Control Centre Module, Signalling Post Module and Level Crossing Gate Module. A safe distance of 1 Km has been maintained between the trains after applying the emergency brake in case of collision detection. Based on the studies, it is observed that even for two trains travelling at 140kmph, the safe distance after automatic braking under normal conditions is approximately 920m. All sub modules have been designed and simulated using Proteus electronic simulation package and the prototype is implemented. It is expected that if this system is implemented widely, train collisions and accidents at the Manned/Unmanned level crossing gate can also be avoided in the future.

Keywords – ZigBee, Proteus, OrCad, Micro Controller, MikroC, Train Anti-collision System.

I. INTRODUCTION

Railway is an Eco-Friendly and Popular mode of Transport in most major cities of the World. Train accidents occur normally due to safety violations resulting from ‘human errors or limitations’ and ‘equipment failures’ loosing precious lives. The Ministry of Railways (Railway Board), Govt. of India has referred Ten Train Collisions in the past for development of an efficient Train Anti-Collision system [3] and the need for research in this field. Konkan railways have proposed and implemented an Anti – Collision System [9]. The system did not take any active inputs from existing Railway signalling system, and also lacked two ways communication capability between the trains and the control centers or stations, hence was later decommissioned.

The goal of this work is to design and implement a cost effective and intelligent full-fledged Train Anti Collision System to prevent the train collisions. It aims to efficiently integrate into the existing signalling system [7] and avoid accidents in manned as well as unmanned level crosses, without changing any of the existing system implemented in Indian Railway. Presently, emergency may be passed through traditional tele-communication systems like Walkie-Talkies or other communication devices, Collision avoidance systems on same track using IR modules and ACD by Konkan Railway. But each of these systems has its own advantages and disadvantages. In the traditional communication method, human error or carelessness may lead to severe disasters as noticed in the past. IR sensors have limitations due to the geographic nature of the tracks. The ACD system also is found to be ineffective as it is not considering any active inputs from existing Railway signalling system, and also lacks two ways communication.
capability between the trains and the control centers or stations, hence has been later decommissioned. Later geographical sensors have also been used which makes use of satellites for communication. But the system is costly and complicated to implement.

The proposed Train Anti Collision and Level Crossing Protection System consists of a self-acting microcontroller [6] and two way ZigBee [5] based data communication system which works round-the-clock to avert train collisions and accidents at the level crosses. Thus enhances safety in train operations by providing a NON-SIGNAL additional safety overlay over the existing signalling system. The system operates without replacing any of the existing signalling and nowhere affects the vital functioning of the present safety systems deployed for train operations. The proposed system gets data from the moving Trains, Control-Centers/Stations, Signalling Posts and Level Crossings. The efficiency of the system is expected to be considerably increased as the proposed system takes inputs from the signal posts and also from the level crossing gates. As more relevant data are included, it is expected that the present system may assist loco drivers in averting accidents efficiently. As no change is necessary to be made to the infrastructure of the existing system, the cost of implementation of this system is also less.

The system has been designed and simulated using proteus real time simulation software. Models of the rail traffic systems has also been made and tested. Various sub modules communicate with each other and with a central monitoring station where entire data is stored and monitored. The rest of the paper is organized as follows. Sections II deal with the proposed system detailing the schematic diagram detailed explanations for various sub Modules [2].Section III details the system of operation. Section IV explains the detailed design. Section V gives the proteus simulation and implementation [2] followed with test results, conclusions and future scope and references.

Figure 1. Overview of the proposed System

II. THE PROPOSED SYSTEM

Figure 1 shows overview of the proposed system. The proposed Train Anti Collision and Level Crossing Protection System consist of a microcontroller and full duplex ZigBee-based data communication system. The entire Network consists of mobile sub modules (on Locomotives and Guard’s Brake Vans), sub module in stations, sub module in level crossing gates and the sub module in railway signal posts. Loco subsystem communicates to other locos within a radius of 3000 meters using radio frequency. The system communicates with the nearest signal posts, Level crossing gates and control stations to continuously monitor various signals arriving in the control center and taking decisions based on the received information.

ZigBee modem [10] communicates with other subsystems providing a mesh interconnection between all subsystems. The control station controls and monitors the all sub modules in the entire network. Whenever a collision-like situation is detected by instinct, the device will automatically taking care and prevents the collision. The whole system is likely to prevent ‘head-on’ and ‘rear-end’ collisions in mid-sections, collisions at ‘high speed’ in ‘station area’, ‘side collisions’ with derailed vehicles and collisions with ‘road vehicles’ at level crossing through ‘Train Approach’ warning, alarm and detection of ‘Gate Open’. Train sub modules also give ‘Station Approach’ warning to loco pilots. Moreover, using manual switches on the train sub module, Drivers, Guards and Station Masters can also ‘stop’ trains when any unusual is detected. Different sub modules when installed on Locomotives (along with their Auto-Braking Units), Guard Vans, Railway signal posts, Stations, Track changing Sections and at Level Crossings (both manned as well as un-manned), form an intelligent full-fledged eventuality detection and prevention. The proposed model makes use of ZigBee protocol [8] as a medium of transferring information. The
data reception and transmission between the different sub modules are performed using Wireless RF data communication system.

The Wireless RF module sends capsules of data as an 8 bit format comprising of the signals obtained from various points described. Figure 2 shows the pictorial representation of the entire system. When all subsystems and control center works in conjunctur e, an efficient Train Anti Collision and Level Crossing Protection System gets implemented.

2.1 Sub Module in Train

The sub module to be stationed in the train has a ZigBee module, a microcontroller unit, and an alarm with necessary driver and power supply units [2]. The role of this sub module in the train is to alert the Loco pilot in case of emergency. In case of threatened collision, emergency braking system takes control and the train will be stopped. The ZigBee modem transceivers data at regular time intervals. The packet contains information such as Track-ID, Direction of movement and train ID. The packets may be received from Control Stations, Level Crossing Gates, Stations, Signal Post and passing Trains. Each time a packet is received; the Track ID, direction of motion and train ID of the train is checked.

![Figure 2. Representation of the Entire System](image)

2.2 Control Centre Sub Module

The Control Center has a ZigBee modem, a microcontroller unit, a PC with software and database and an alarm with drivers and power supply units. The role of the sub module is to process the data received from other sub modules in the coverage area and broadcast it to the requested sub modules. The data updating has to be accomplished with the aid of the control center. The ZigBee modem sends the updated data and receives the data to update at regular time intervals. The 8-bit control sub center packet contains information such as Track-ID, Direction of movement, Train ID and Control Bits [2],as shown in the data frame format.

2.3 Level Crossing Gate Sub Module

The Level Crossing Gate sub module [2] has a ZigBee modem, microcontroller unit, an alarm and visual display with necessary driver and power supply units. This sub module continuously checks for data received from passing trains. When the train approaches at 3 km distance from the level crossing, the alarm circuit and visual display alert circuit gets activated. This helps the pedestrians and vehicles to stay away from the railway track when the train passes.

2.4 Signal Post Sub Module

The fourth sub module deployed in the Signal Post [2] has a ZigBee module and a microcontroller with drivers and power supply units. The role of this sub module is to send data based on color of present light in the signal post. If the light is red then the module will send the data to stop the train, if yellow, it sends the data to alert the loco pilot to reduce the speed.
III. SYSTEM OPERATION

Train Anti-Collision and Level Crossing Protection sub modules that are within a radial range of 3Kms, communicate with each other, and based on train working rules programmed in them, take decisions automatically, without any input from their users, triggering automatic brake applications through Train Sub modules. If two trains are seemed to be at risk of collision, thereby preventing dangerous collisions or minimizing the extent of damages that may be caused by collisions in mid-sections and station areas resulting in saving the lives of human beings. Further, added responsibilities have also been assigned to the Network in the form of ‘Administrative’ requirements namely, Train Sub module to ‘alert’ Driver on ‘Station Approach’ and also to trigger ‘Train Approach’ warning at Level crossings for the road users. For their operations, various sub modules derive inputs from locomotives, stations, existing signalling systems, track changing sections, level crossing gates etc.

The emergency braking distance \[4\] is obtained as approximately 400 meters for a train travelling at 140 Km/h \[7\]. The wireless modules proposed here have a range of 3 Kms and two trains moving head on can be safely detected within a distance of approximately 3 Kms without errors \[1\]. Considering the braking distance of 1000 meters per train, both trains can be stopped within a safe distance of 920 meters. Track IDs of trains can be changed with the help of RF tags on tracks whenever a track change gets detected \[1\]. Tracks may also be embedded with track changing section sub modules to continuously monitor and correct track IDs. A simple and an efficient algorithm and flowcharts for various sub Modules have been developed \[1\].

The ZigBee modem sends and receives data at regular time intervals as 8-bit data frame. The packet contains information such as Track-ID, Direction of movement and train ID. The packets may be received from Control Stations, Level crossing Stations, Signal Posts and Passing Trains. Each time, a packet is received, the Track ID and the Direction of motion of the train is checked.
If the Track IDs are same and the Direction of motion of the trains is opposite, then both the Trains are automatically stopped by emergency braking to avoid the head on collision. If same track IDs with same direction, the Train, the Train with higher Train ID will be stopped automatically to prevent rear end collision. The 8-bit data frame format of the TACS system is shown in TABLE I.

The D7 field of the 8-bit data frame is assigned for the Direction selection. The D6 and D5 fields are used for the Track ID. The Control bits, namely D4 and D3 bit fields are assigned for the acknowledgement and sending of data to the trains from the Miniature Control Centre respectively. The rest of the bit fields are assigned for the 3-bit Train ID.
IV. DETAILED DESIGN

The proposed Train Anti Collison System consists of a ‘self-acting’ microcontroller and two ways ZigBee based data communication system which works round-the-clock to avoid train collisions and accidents at the level crosses. The system operates without replacing any of the existing signalling and nowhere affects the vital functioning of the present safety systems deployed for train operations. All the circuit diagrams [2] and the corresponding PCB layouts are designed using the OrCAD 9.1 software. The microcontroller used here for the implementation is PIC16F873A and the microcontroller programming has been performed using MikroC.

V. SIMULATION AND IMPLEMENTATION

Various test conditions based on data acquired during literature survey were fed as input to the simulation in Proteus [2]. Results of the simulation was observed to be positive and coincide with proper system of operation. The circuits after successful simulation are being designed [2] and fabricated. PCB lay outs and final boards are shown in Fig.3. Front end development of the Control Centre has been carried out using Microsoft visual studio [12]. The snapshot of final implemented prototype and the front end is shown in Fig.4.

VI. TEST RESULTS

This project realizes an efficient Train Anti-Collision and Gate Protection System based on the emerging wireless communication technology, and has implemented both hardware and software of Train sub Module, Station sub Module, Signal Post Sub Module, Level Crossing Gate Sub Module and Control Center. Decisions are arrived at based on train to train communication and also with the existing railway signalling system which is made possible by the four independent sub modules. Results of testing the fabricated circuit are discussed.

All the conditions with different test parameters (Track ID, Direction, Train ID) for different scenarios have been tested and verified. Some of them are shown in TABLE II.

VII. CONCLUSIONS AND FUTURE SCOPE

In this paper, a design for automatically averting train collisions and accidents at level crossing gate have been designed, simulated and tested.
The simulation has been done using proteus and testing has been carried out using the developed prototype. It has been estimated that, a train travelling at a speed of 140 Km/h can be stopped at 400 meters under normal conditions. As this proposed system has the capability of identifying trains in the same track at a distance of 3000 meters, it can be seen that even if the two trains travel at a speed of 140 Km/h that can be halted with a safe distance of 900+ meters between them providing a tolerance of 600 meters for banking. Also this system gets active inputs from the signal posts and level crossings, the reliability and efficiency of this system if implemented are expected to be high.

On the basis of such considerations, the algorithm uses a different color image multiplied by the weighting coefficients of different ways to solve the visual distortion, and by embedding the watermark, wavelet coefficients of many ways, enhance the robustness of the watermark.

As future expansion it is proposed that licensing procedures of satellite communications [11] may be initiated so as to implement a system upgrade whereby real time data of moving trains like speed and current location may be tracked and monitored at the control station. Such real-time information can be utilized for system upgrade so as to avert accidents due to natural calamities such as land slide and cyclone. An additional geographic sensors and interface with geographic information system may be required for the same. Panic buttons may be provided in all compartments of the train which may be used by passengers in case of danger and alert the control station. Algorithm of the proposed system may also be altered so as to incorporate a cruise control such that whenever speed of train is detected to be higher than a rated level automatic brake may be applied. Automatic slowdown of trains when approaching stations without stops may also be implemented as per requirements from Indian Railways.

### TABLE II. TEST RESULTS

<table>
<thead>
<tr>
<th>Test Seq.</th>
<th>Track ID</th>
<th>Data of Train T1</th>
<th>Status of Train T1</th>
<th>Data of Train T2</th>
<th>Status of Train T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>x</td>
<td>0 1 2 3</td>
<td>129</td>
<td>x</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>2</td>
<td>x</td>
<td>1 2 3 4 5 6</td>
<td>36</td>
<td>x</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>3</td>
<td>x</td>
<td>1 2 3 4 5</td>
<td>71</td>
<td>x</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>4</td>
<td>x</td>
<td>1 2 3 4</td>
<td>36</td>
<td>x</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>5</td>
<td>x</td>
<td>1 2 3</td>
<td>132</td>
<td>x</td>
<td>1 2 3</td>
</tr>
<tr>
<td>6</td>
<td>x</td>
<td>1 2</td>
<td>DTOD</td>
<td>R</td>
<td>DTOD</td>
</tr>
</tbody>
</table>

*STOD – Same Track Opposite direction; STSD – Same Track Same Direction; DTOD – Different Track Opposite Direction; DTOD – Different Track Same Direction; 5 – Stop; R – Running.

### Test Results for Train to Signal Post Communication.

<table>
<thead>
<tr>
<th>Signal Post Data</th>
<th>Test Seq.</th>
<th>Data of Train T</th>
<th>Status of Train</th>
</tr>
</thead>
<tbody>
<tr>
<td>I^th track, Direction Bit 0, Assigned with Highest Train ID, Data frame - 39a</td>
<td>1</td>
<td>1 2 3</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>x</td>
<td>S</td>
</tr>
</tbody>
</table>

*STOD – Same Track Opposite direction; STSD – Same Track Same Direction; DTOD – Different Track Opposite Direction; 5 – Stop; R – Running.

### Test Results for Train to Level Crossing Gate Communication.

<table>
<thead>
<tr>
<th>Train in the L/C Module Range</th>
<th>Status of L/C Gate Light</th>
<th>Alarm in the L/C Gate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Absent</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

*L/C – Level Crossing.
REFERENCES


[4] David Barney David Haley and George Nikandros: Calculating Train Braking Distance, Signal and Operational Systems Queensland Rail PO Box 1429, Brisbane 4001, Queensland, Australia


