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Zigbee based prototype design of anti-collision system for locomotives

[1] Atul Sarojwal, [2] PP Singh, [3] AK Gupta
[1] Asst. Professor, Department of Electrical Engineering, FET, MJP Rohilkhand University, Bareilly, Uttar Pradesh, India
[2] Professor & Dean Student Welfare, Invertis University, Bareilly, Uttar Pradesh, India
[3] Professor & Dean, Department of Electrical Engineering, FET, MJP Rohilkhand University, Bareilly, Uttar Pradesh, India

Abstract
Anti-Collision System for Railways is used to avoid train accidents. The system proposed in this paper involves the use of encrypted Zigbee protocol where Zigbee modules are placed along with the train engine to avoid Head-On or Rear-End collisions of trains. One of the major benefit of the concept presented in this research paper is that even if the trains are running over different tracks, trains of only individual same track will receive signals to avoid collision and the nearby track trains will keep continue to run. If two trains are coming on the same track, they will get stopped with a safe distance between them. The Train module, Zigbee module, Control Module and Braking Module are incorporated together to form Anti Collision System proposed here.

Keywords: anti collision system, locomotives, Zigbee, microcontroller, track

1. Introduction
Railway, now a days, has become an important mode of transportation. Trains are running at higher speed than ever before with increased number of passengers to cope up with the factors like time limitations, busy schedule of life and increase in population etc. For longer distance people prefer railway journey rather than by their own vehicle as it cheaper, time saving and also easily approachable. Therefore it has become incumbent for railway to be a safe mode of transportation. Despite of different possible methods, techniques and new technological developments by different countries worldwide, train collisions are taking place and every time a collision takes place it is at the sake of life of thousands of passengers or human beings travelling through the trains. In the proposed method Zigbee technology is used where Zigbee Receivers and Transmitters are fitted over engine of the each and every train running over the tracks. When the two trains comes on the same track, Zigbee modules receives signal and immediately forward the same to control unit for activating the braking system. The proposed system utilizes Zigbee transmitter and receiver, Microcontroller, X-CTU Software, Relay Mechanism, buzzers, batteries etc.

2. Train Collisions and Derailment
Railway accidents are now become a common thing as they are taking place regularly. Throughout the world train accidents are taking place. Possible collision situations are:

2.1 Head-On Collision
When two locomotives are running towards each other, front to front or head on collision takes place.

2.2 Front to Back Collision
When two locomotives are running on the same track and in the same direction or one is stationary and another is moving towards it from back end, front to back or rear-end collision takes place.

2.3 Derailment
When train or locomotive gets derailed due to discontinuity of the track or uncontrolled speed.

3. Reasons
Improper communication within the network
Worst signaling
Worst weather condition
Low attention of driver
Uncontrolled speed
Discontinuity of track

4. Existing Methods
Different methods have been developed and implemented to avoid train collisions but not that much worth-while. Positive Train Control (PTC) initiated by National Transportation Safety Board (NTSB), USA. Anti-Collision Device (ACD) is a train collision prevention system patented by Konkan Railway Corporation in India. Train Protection Warning System (TPWS) commissioned in southern railways, India. Train Collision Avoidance System (TCAS) commissioned in Mumbai, India.

5. Proposed Method
In the proposed method Anti Collision System for Locomotives is divided into various modules i.e. Train Module, X-CTU software, Controlling Module, Actuating Module, Zigbee Module and Braking Module.

5.1 Train Module
Train Module is confined for a particular encryption of Zigbee transmitter and receiver related to an individual track. Train

module is driven by an actuator corresponding to individual track. It does not matter that how many trains are present over a particular track. All the trains will have same encryption of Zigbee transmitters and receivers placed on their locomotives. Encryption is to be provided with the help of X-CTU software. Corresponding to the possible number of tracks running parallel, the same number of sets of Zigbee modules are to be placed over locomotives of trains. One particular set of module is for one particular track.

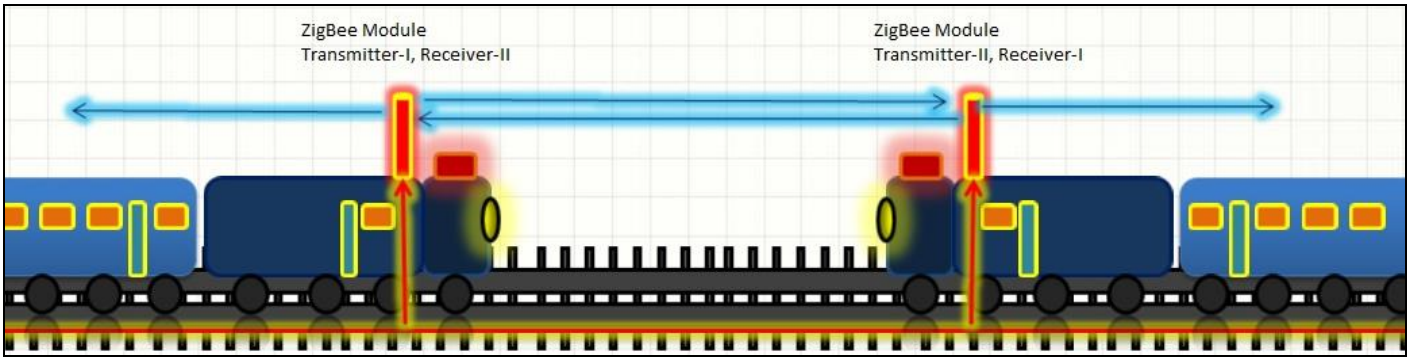

Fig 1: Train Module Setup

5.2 XCTU

XCTU is a free multi-platform application designed to interact with Zigbee modules through a simple to use graphical interface. It includes tools that make it easy to set-up, configure and test Zigbee RF module. The communication among multiple Zigbee modules can be made possible by managing and configuring them with the same PAN ID.

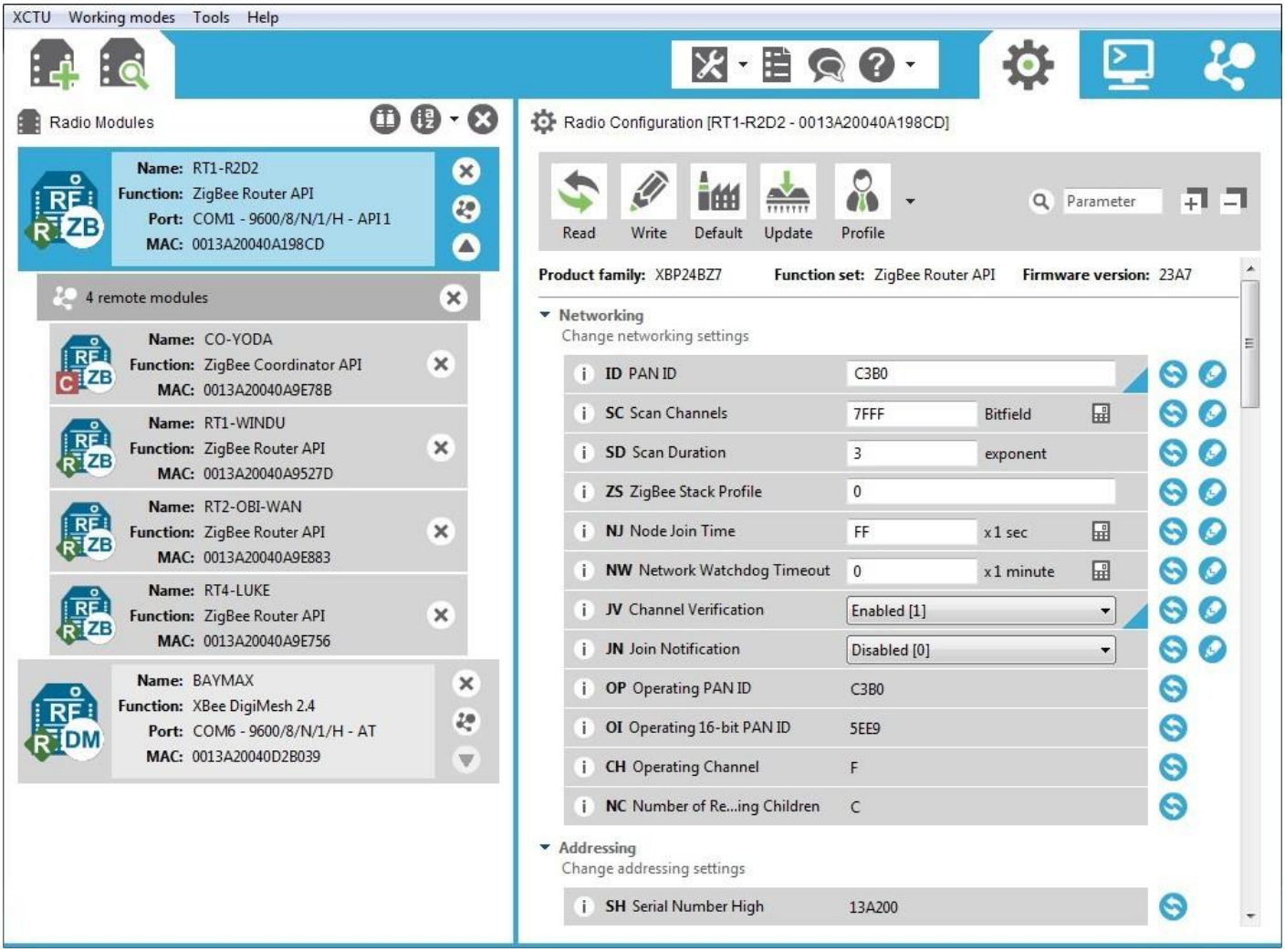

Fig 2: Xctu Software Setup

XCTU is a free multi-platform application designed to interact with Zigbee modules through a simple to use graphical interface. It includes tools that make it easy to set-up, configure and test Zigbee RF module. The communication among multiple Zigbee modules can be made possible by managing and configuring them with the same PAN ID.

5.3 Controlling Module

The controlling module includes high performance 8-bit AVR RISC based microcontroller ATmega328 that combines 32KB ISP flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working resisters, three flexible timer/ counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter, programmable watchdog timer with internal oscillator and five software selectable modes. The microcontroller operates between 1.8 to 5.5 volts. Commonly implementation of ATmega 328 is on Arduino development platform i.e. Arduino Uno or Arduino Nano. In the present system Arduino Uno is used. It is programmed through Arduino Programmable Software with the help of Arduino board. Train module sends track identity information to control module which further forwards it to actuating module. For a particular track in proposed system input pin 2 & 3 are used and corresponding output pins 11 & 12 are used.

5.4 Actuating Module

This module comprises the combination of transistors, relays and resistors for forwarding the signal received from controlling module to right Zigbee module so that the train braking mechanism can be activated.

NPN Transistor BC548: $I_{c\ max}$ = 500mA, h_{fe} = 200

Relay: SPDT, 6-9V, r = 100ohm, I = 60mA

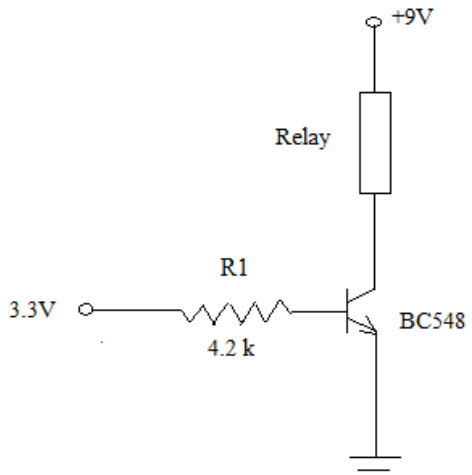

Fig 3: Actuating Module

Resistor connected with transistor base: 4.2K with voltage from controlling module 3.3V to limit the base current.

Transistor BC548 is used as a switch along with SPDT 100ohm relay so that it can be operated at low voltage actuating signal received from controlling module.

5.5 Zigbee Module

Zigbee module used in the proposed system incorporates series S1 modules based on IEEE 802.15.4 standards. The specifications of module includes:

Table 1: Zigbee Specifications

Data Rate	250 kbps
Indoor/ Urban Range	100 ft
Outdoor/ Line of sight range	300 ft
Digital I/O	8
Frequency Band	2.4 GHz
Transmit Power	1 mW
Supply Voltage	2.8-3.4 VDC

There can be number of trains running on a particular track. Based on maximum possible number of trains that can run on a track, the same number of Zigbee modules are to be placed in a single set of modules for a particular track. All these modules will have the same level of encryption with respect to receiver transmitter pairs. As soon as any train comes on a track, the set of Zigbee modules corresponding to that track will get activated automatically. The transmitters and receivers pairs present in the modules will transmit and receive signals and these signals will be further sent to braking module to stop the Locomotive.

Placement of Zigbee modules for individual track is as shown below:

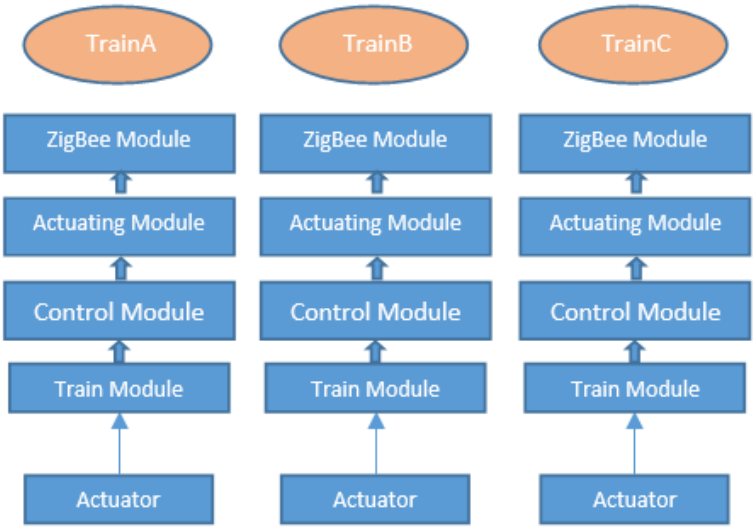

Fig 4: Zigbee Module Setup for Individual Track

5.6 Braking Module

Braking Module is connected after Zigbee module to stop the Locomotive. As soon as Zigbee module gets activated after receiving the signal from other train coming on the same track, it further send the signal to braking module which immediately apply the brakes to stop the train. In this project braking module disconnects the supply of model trains to stop them.

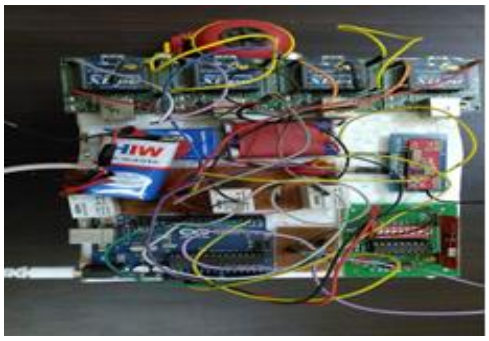

Fig 5: Fabricated Board

Fig 6: Testing Phase for Individual and Separate Track

6. Testing and Results

The project provides an effective Anti-Collision System for Locomotives based on the emerging Zigbee wireless communication technology. It has both hardware and software of Train Module, Controlling Module, Actuating Module and Zigbee Module. Activation of Zigbee is based on train to train communication. In Indian Railways the average speed of train is around 100 km/hr. After braking train travels a distance of about 500 m due to inertia. Therefore safe distance between trains travelling towards each other should be 1.5 km so that even after braking trains must stop at a safe distance from each other.

In this project the speed of train is 1 km/hr, then after braking due to inertia (as compared with practical situation) it should travel up to a distance of

$$500/100 \text{ X } 1 = 5 \text{ meter}$$

Thus two trains will travel a distance of (5 + 5) = 10m.

Therefore the range of Zigbee Module in this project is kept around 15 meter so that even after travelling 5m by each train after brakes applied, they still separated by a safe distance of 5 meter.

Table 2: Testing and Results

Testing Phase (On Same Track)	Distance Between Trains After Stop
1	6 m
2	5.5 m
3	6 m

7. Conclusions and Recommendations

The project presented here is practically tested and verified. It can safely be incorporated with Railways for Anti-Collision practice i.e. collision can be avoided and at the same time cost can be reduced up to considerable extent. Zigbee module provides wireless technology that can be used to avoid collisions. As it totally automatic system therefore it avoids dependency upon weather, human beings as well as satellite.

This project can be made more efficient by introducing the concept of derailment due to discontinuity present in the tracks due to various reasons. If discontinuity of tracks can be judged earlier then derailment can be avoided and train accidents in such cases can be stopped.

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