"ZigBee Wireless Sensor Based Prototype Design for Avoidance of Train Accidents due to Derailment Caused by Track Discontinuation"

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ABSTRACT: ZigBee based system presented here for Railways is designed to avoid train accidents due to derailment caused by track discontinuation. The set of encrypted ZigBee modules, i.e. ZigBee transmitters and ZigBee receivers are used in the proposed design. Transmitters are placed near the railway track at regular intervals and receivers are placed at locomotive that is train engine. The advantage of the design proposed in this research paper is that if any train is running over a track and discontinuity of the track takes place due to any possible reason then the train passing through that track will automatically get stopped. Also the system is designed in such a way that at the time of track discontinuation, in addition to train stopping an alarming buzzer signal will also be sent to the control room of nearby station. The Train module, ZigBee Module, Track Side Transmitter Module, Actuating Module and Braking Module are incorporated together to form system for accident avoidance due to derailment of trains caused by discontinuities present in the tracks.

Key-words: ZigBee, Derailment, Locomotives, Microcontroller, Track, Buzzer

1.   INTRODUCTION

Indian Railways provides the most important mode of public transportation in India .This is the most commonly used and cost effective long distance transport system of the country. Indian Railway is touching the life of almost every people across India covering 29 states and 7 Union Territories with its over 40,050 miles railway network. Indian Railway is the 4th largest railway in the world which is transporting around 7651 million passengers. The need of Railways is felt by every Indian. In the current Railway systems, it is becoming even more necessary to have safety elements in order to avoid accidents. The train safety has been an issue with the increasing no of accidents being reported that have caused deaths and injuries. In the fast developing country, people are facing many accidents; it would be undesirable for any nation to lose lives of their citizens for unwanted cause. The accidents in Railways are due to two major reasons i.e. Head on Collisions and track discontinuation problems which lead to derailment. Even though various technologies have been implemented by Indian Railways to avoid the collisions and detect the cracks in railway tracks

but the accidents are still taking place due to collisions and derailments. In order to avoid this situation, there is a need of automatic anti-collision and crack detection system in Railways. In the system proposed here ZigBee wireless technology is used where ZigBee Receivers are fitted over engine of the each and every train running over the tracks and ZigBee transmitters are laid along track side. When there is discontinuity present in any track and if the train is coming over it, ZigBee module receives the signal immediately from the track side ZigBee transmitter within the range and it forwards the signal to control unit and actuating unit for activating the braking system. The proposed system utilizes ZigBee transmitter and receiver, Arduino Uno with ATMega 328P Microcontroller, Relay Mechanism, Buzzers and Batteries etc.

2.   TRAIN ACCIDENTS

Most of the train accidents are taking place due to two main reasons, i.e. Derailment which is mainly caused by track discontinuation and collisions caused by presence of two or more trains on the same track due to wrong signaling. Frequency of train accidents is almost constant even after so many new protection schemes which have been developed and implemented. Train accidents are not hidden any more. Everywhere in the world train accidents are taking place. Train accidents may take place due to following reasons:

2.1   Derailment

When the train gets derailed due to discontinuity of the track or if brakes are applied at an uncontrolled high speed, derailment takes place. Also if any problem comes in the wheels or axle of the wheels, derailment can take place.

2.2   Head-On Collision

When two trains are running towards mismatch communication or wrong signaling by the operator at station, the situation of head on collision takes place.

2.3   Rear-End Collision

When the two trains 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.

3.   REASONS OF TRAIN ACCIDENTS

Discontinuity of track
Carelessness by staff
Low attention of locomotive driver
Mismatch of communication
Wrong signaling
Poor weather condition
Uncontrolled speed

4.   EXISTING METHODS

Existing methods of the train protection are as follows:

4.1   Anti Collision Device (ACD) & Track Identification System By Konkan Railway

An anti-collision device for trains and the like transportation system comprising of a microprocessor based command and control unit (CCU), a Global Positioning System (GPS) with satellite signal receiver antenna, a crew interface of desired capacity/range with directional antenna, a braking signal unit linked with braking mechanism for locomotive speed control, a message display unit having audio and/or visual display means and a power supply system, preferably consisting of a battery and power converter, all units and systems functionally interconnected.

A track identification system for a number of locomotives moving on defined number of tracks of a railway network wherein the system consists of on board computers with track data and identifiable switching locations data and the parameters of movement of the locomotives along the said tracks.

4.2   Positive Train Control By USA

Positive train control (PTC) is a system of functional requirements for monitoring and controlling train movements to provide increased safety. The American Railway Engineering and Maintenance-of-Way Association (AREMA) describes Positive Train Control as having these primary characteristics:

- Train separation or collision avoidance
- Line speed enforcement
- Temporary speed restrictions

4.3   Train Protection and Warning System

A standard TPWS installation consists of an on-track transmitter placed adjacent to a signal and activated when the signal is at `danger' point. Any train that tries to pass the signal will have its emergency brakes activated. If the train is travelling at speed, this may be too late to stop it before the point of collision, therefore a second transmitter may be placed on the approach to the signal that applies the brakes on trains going too fast to stop at a signal, and this is positioned to safely stop trains approaching at upto 120 km/h.

4.4   Train Collision Avoidance System

TCAS was designed to suit local requirements to provide protection by ensuring trains do not pass signal at danger, controlling speed at turns, restricting speed, avoiding collisions when more than one train is on the track. Loco pilots get real-time display of signals inside the cabin, also indicating the distance to be travelled safely. It improves the safety in train operations and also allows loco pilots to drive trains at maximum speed with confidence. This system employs the use of central TCAS station that controls the system and also GPS navigation.

5.   PROPOSED METHOD

The modules of the method proposed for avoidance of train accidents due to derailment caused by track discontinuation are as follows: Track Side Transmitter Module, Train module, ZigBee Module, XCTU Software, Actuating Module and Braking Module.

5.1   Track Side Transmitter Module

In the method proposed here ZigBee modules are used for transmitting and receiving the signals. The transmitter ZigBee module is placed along with track in such a manner that if track gets discontinued due to any of the possible reasons, i.e carelessness of the workers, sabotage activity or losing of the fish plates then transmitters will automatically get activated. Arduino Uno is connected along with ZigBee module to give the required supply to the module. ZigBee transmitter will send the signals which are received by the receivers placed over the train locomotive. For each and every track running parallel, such arrangement has been made. In addition to transmitter arrangement made on the track side, a buzzer system is also arranged in such a manner that if track gets discontinued it will activate the buzzer system to produce an alarming signal.
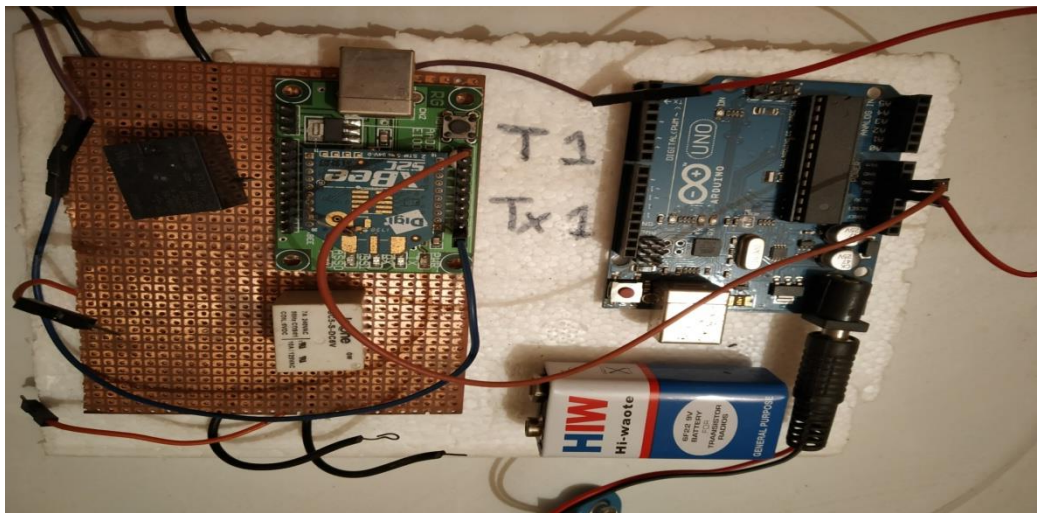

Fig.1: TRACK SIDE TRANSMITTER MODULE

5.2   Train Module

Train Module involves the use of ZigBee module receiver with Actuating and braking circuitry. ZigBee transmitter and receiver are encrypted. ZigBee encryption is in accordance witheach and every individual track running parallely. ZigBee receiver present in the locomotive is controlled by the transmitters corresponding to individual track. Regardless of how many trains present over a particular track, all the trains will have common encryption of ZigBee receiver and transmitters. ZigBee module is encrypted with the help of XCTU software by setting up the PAN ID of ZigBee transmitters and receivers. Based on the number of tracks running parallel, the equal number of ZigBee receiver setsare to be kept over trains so that whenever shunting of engines takes place it will not affect the circuitry and ZigBee receivers will be activated corresponding to that particular track.
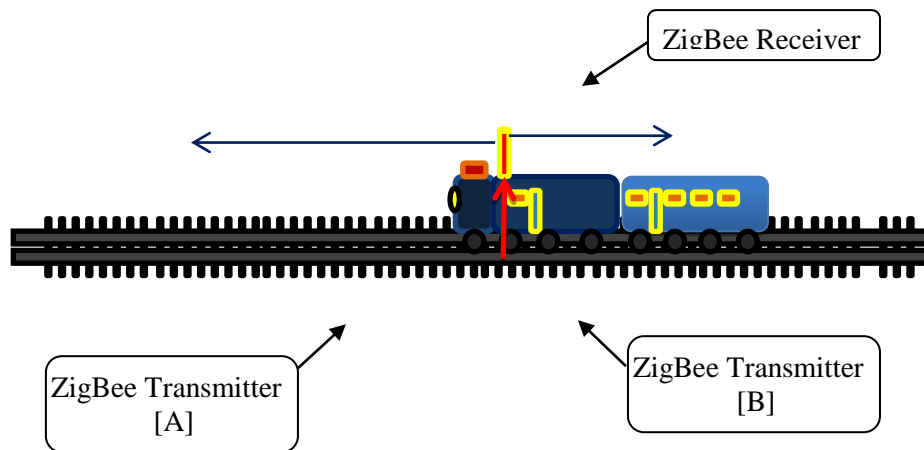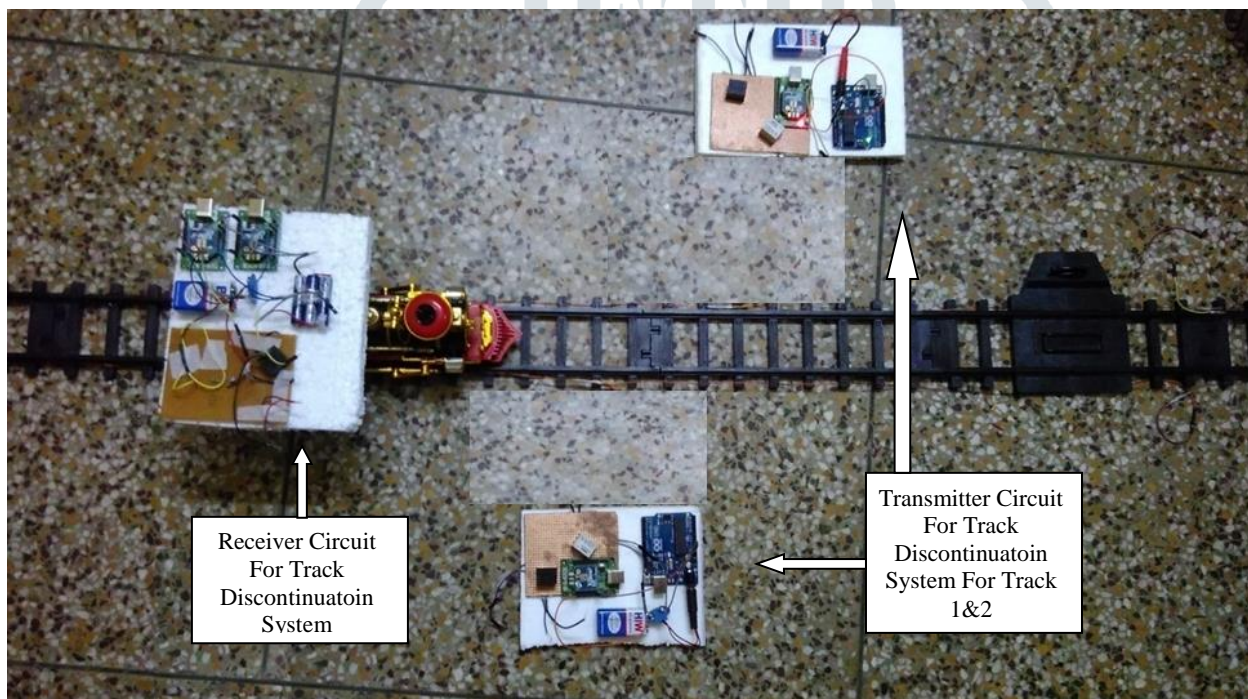
Fig.2: TRAIN MODULE WITH ZIGBEE SETUP

Fig.3: ACTUAL IMAGE OF TRAIN MODULE WITH ZIGBEE SETUP

5.3   ZIGBEE Module

ZigBee or XBee 802.15.4 RF modules provide OEMs with a common footprint shared by multiple platforms, including multi point and ZigBee/Mesh topologies, and both 2.4 GHz and 900 MHz solutions. OEMs deploying the ZigBee can substitute one ZigBee by another, depending upon dynamic application needs, with minimal development, reduced risk and shorter time-to-market.

Specifications:

o   RF Data Rate: 250 kbps

o   Indoor/Urban range: 100 ft (30 m)

o   Outdoor/RF Line-Of-Sight range: 300 ft (100 m)

o   Transmit power: 1 mW (+0 dBm)

o   Receiver sensitivity (1% per): -92 dBm

o   Supply voltage: 2.8 - 3.4VDC

o   Transmit current: 45 mA @ 3.3VDC

o   Receive current: 50 mA @ 3.3VDC

o   Power-down current: <10 uA @ 25° C

5.4   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.4: XCTU SOFTWARE SETUP

5.5   Actuating Module

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

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

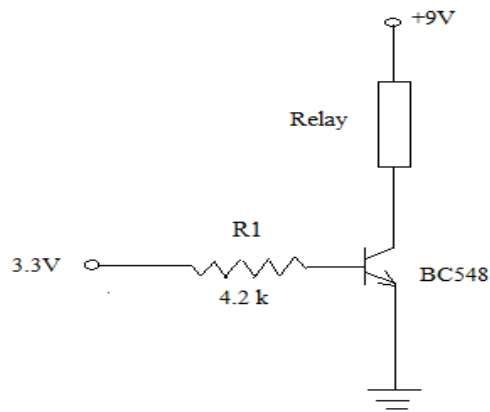Relay: SPDT, 6-9V, r = 100ohm, I = 60mA

Fig.5Actuating Module

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 ZigBee module.

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

5.6   Braking Module

Braking Module is connected after ZigBee module to stop the train. As soon as ZigBee module gets activated after receiving the signal from track side transmitter module, it further sends the signal to actuating module. Actuating module sends the signal to braking module which immediately applies the brakes to stop the train. In this project braking module disconnects the supply of model trains to stop them with the help of SPDT relay.

In case of track discontinuation, the activation serial plan for the ZigBee transmitter and receiver modules to stop the train will be as follows:

Case1: Train1 on track1 and train2 on track2 and track1 discontinues

Train1:	Train2:	Track1:	Track2:
RX1----Active	RX1----Active	TX1----Active	TX2----Inactive
RX2----Active	RX2----Active		

Case2: Train1 on track1 and train2 on track1 and track1 discontinues

Train1:	Train2:	Track1:	Track2:
RX1----Active	RX1----Active	TX1----Active	TX2----Inactive
RX2----Active	RX2----Active		

Case3: Train1 on track1 and train2 on track2 and track2 discontinues

Train1:	Train2:	Track1:	Track2:
RX1----Active	RX1----Active	TX1----Inactive	TX2----Active

RX2----Active   RX2----Active

Case4: Train1 on track1 and train2 on track1 and track2 discontinues

Train1:	Train2:	Track1:	Track2:
RX1----Active	RX1----Active	TX1----Inactive	TX2----Active
RX2----Active	RX2----Active		

Case5: Train1 on track2 and train2 on track2 and track1 discontinues

Train1:	Train2:	Track1:	Track2:
RX1----Active	RX1----Active	TX1----Active	TX2----Inactive
RX2----Active	RX2----Active		

Case6: Train1 on track2 and train2 on track1 and track1 discontinues

Train1:	Train2:	Track1:	Track2:
RX1----Active	RX1----Active	TX1----Active	TX2----Inactive
RX2----Active	RX2----Active		

Case7: Train1 on track2 and train2 on track2 and track2 discontinues

Train1:	Train2:	Track1:	Track2:
RX1----Active	RX1----Active	TX1----Inactive	TX2----Active
RX2----Active	RX2----Active		

Case8: Train1 on track2 and train2 on track1 and track2 discontinues

Train1:	Train2:	Track1:	Track2:
RX1----Active	RX1----Active	TX1----Inactive	TX2----Active
RX2----Active	RX2----Active		

6.   TESTING AND RESULTS

In the testing phase two trains were allowed to run on the two parallel tracks one by one and the discontinuity condition was made to check whether train stops at a significant distance from the discontinued part or not.

Case1: For trains running on track1

Track Length: 10 meters
Speed of model train: 1km/hr
After Track Discontinuation

Point of track discontinuation: 3 meters form train1 and 7 meters from train2

Distance between the trains when started: 10 meters (on same track)

Distance of Train1 from point of discontinuation when stopped: 2.5 meters

Distance of Train2 from point of discontinuation when stopped: 4.7 meters

Time taken by the train1 to stop: 1 seconds

Time taken by the train2 to stop: 4 seconds

Signal Range of transmitter: 5 meters (approx.)

Result: Both the trains stopped

Case2: For trains running on track2

Track Length: 10 meters

Speed of model train: 1km/hr

After Track Discontinuation

Point of track discontinuation: 3 meters form train1 and 7 meters from train2

Distance between the trains when started: 10 meters (on same track)

Distance of Train1 from point of discontinuation when stopped: 2.6 meters

Distance of Train2 from point of discontinuation when stopped: 4.8 meters

Time taken by the train1 to stop: 1 second

Time taken by the train2 to stop: 4 seconds

Signal Range of transmitter: 5 meters (approx.)

Result: Both the trains stopped

7.   CONCLUSIONS AND RECOMMENDATIONS

The proposed research concept is well tested at each at every phase, i.e. whether the trains are running on the same track or different tracks. After testing of different possible cases it is found that the proposed system is efficient enough to avoid the train accidents due to derailment caused by track discontinuation. The system can be implemented in Indian railways after few modifications which are necessary to implement the system at large scale. This proposed research system is undoubtedly cost effective in comparison to other proposed or implemented systems. The use of ZigBee module for such a system is benefiting factor due to range criteria.With the use of ZigBee module the distance at which locomotive is to be stopped before discontinuation of track can be set with more ease as the range of ZigBee modules if very high. Thus the train accidents due to derailment caused by track discontinuation can be stopped by use of ZigBee wireless sensor.

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