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Prevention of Train Accidents Using Wireless Sensor Networks

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Abstract
This work is concentrated on predicting the major cause of railway accidents that is collision on the same track. The primary goal of this anti-collision system is to identify collision points and to report these error cases to main control room, nearby station as well as grid control stations. So that if any collision likely to occurs then this system will help to avoid such conditions by giving an alarm to concern units. Implementation of an efficient Zig-Bee based Train Anti-Collision for railways is being proposed in this paper. A safe distance of 1 Km has been maintained between two trains after applying the emergency brake in case of collision detection. Based on the studies, it is observed that even for two trains traveling 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 can be avoided. The up-gradation is also done by following the idea of checking cascaded connection of the compartments in sequence manner.

Keywords:- microcontroller, protocol, pressure, sensors, wireless transceiver, Zig-Bee, Proteus, Anti-collision system.

I. Introduction

In these days train accidents are most common and the damage due to these accidents are more severe and takes many lives of passengers hence to reduce the accident rate due to collision and breakage of rails can be reduced to maximum by the means of designing a system that makes use of network to a limited area (using a Zig-Bee module), microcontroller for monitoring the Zig-Bee module, train motor, LCD display, sensors, and a part of internal memory for dumping the required program (in Keil). The design cost is low and the use of the designed system reduces collision between opposite trains on the same train and even when the train is switching between two tracks. Each train contains a single system or a spare one. The Zig-Bee module is described below:

Zig-Bee is a specification for a suite of high level communication protocols used to create personal area networks built from small, low-power digital radios. Zig-Bee is based on an IEEE 802.15 standard. Though low-powered, Zig-Bee devices often transmit data over longer distances by passing data through intermediate devices to reach more distant ones, creating a mesh network; i.e., a network with no centralized control or high-power transmitter/receiver able to reach all of the networked devices. The decentralized nature of such wireless adhoc networks make them suitable for applications where a central node can't be relied upon.

Zig-Bee is used in applications that require a low data rate, long battery life, and secure networking. Zig-Bee has a defined rate of 250 kbit/s, best suited for periodic or intermittent data or a single signal transmission from a sensor or input device. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that requires short-range wireless transfer of data at relatively low rates. The technology defined by the Zig-Bee specification is intended to be simpler and less expensive than other WPANs, such as Bluetooth or Wi-Fi.

Zig-Bee networks are secured by 128 bit symmetric encryption keys. In home automation applications, transmission distances range from 10 to 100 meters line-of-sight, depending on power output and environmental characteristics.

Zig-Bee uses the **direct-sequence spread spectrum** (**DSSS**) is a modulation technique. As with other spread spectrum technologies, the transmitted signal takes up more bandwidth than the information signal that modulates the carrier or broadcast frequency. The name 'spread spectrum' comes from the fact that the carrier signals occur over the full bandwidth (spectrum) of a device's transmitting frequency. Direct-sequence spread-spectrum transmissions multiply the data being transmitted by a "noise" signal. This noise signal is a pseudorandom sequence of 1 and −1 values, at a frequency much higher than that of the original signal. The resulting signal resembles white noise, like an audio recording of "static". However, this noise-like signal can be used to exactly reconstruct the original data at the receiving end, by multiplying it by the same pseudorandom sequence (because 1 × 1 = 1, and −1 × −1 = 1). This process, known as "de-spreading", mathematically constitutes a correlation of the transmitted PN sequence with the PN sequence that the receiver believes the transmitter is using.The resulting effect of enhancing signal to noise ratio on the channel is called *process gain*. This effect can be made larger by employing a longer PN sequence and more chips per bit, but physical devices used to generate the PN sequence impose practical limits on attainable processing gain.

If an undesired transmitter transmits on the same channel but with a different PN sequence (or no sequence at all), the de-spreading process results in no processing gain for that signal. This effect is the basis for the code division multiple access (CDMA) property of DSSS, which allows multiple transmitters to share the same channel within the limits of the cross-correlation properties of their PN sequences. Used in Radio-controlled model vehicles.

II. Indian Railways & Safety

2.1 present Perspective Indian

Railways are the world's second-largest railway, with 6,853 stations, 63,028 kilometers of track, 37,840 passenger coaches and 222,147 freight cars. Annually it carries some 4.83 billion passengers and 492 million tons of freight cars.Of the 11 million passengers who climb aboard one of 8,520 trains each day, about 550,000 have reserve d accommodations. Safe transportation of passengers is the key business objective of any transportation system. Railways are recognized as the safest mode of mass transportation and Safety has been recognized as the key issue for the railways and one of its special attributes. All business strategies emanate from this theme and strive to achieve Accident Free System. Safety is, therefore, the key performance index which the top managements need to monitor and take preventive steps based on trends of accidents which are the manifestations of some of the unsafe practices on the system.

2.2Collisions

Collisions are the most dreaded accidents. It is very difficult to stop such collisions because of speed of moving trains, which need a lead distance to stop. Collisions happen due to human errors and/or faulty equipment.

2.2.1 Head-On & Rear-End-Collisions

A head-on collision is one where the front ends of two ships, trains, planes or vehicles hit each other, as opposed to aside-collision or rear-end collision.. With rail, a head-on collision often implies a collision on a single line railway.

Figure-1 Head- on- Collision

Figure-2 Rear-end- Collision

2.3 Current Technologies used

The Anti-Collision Device (ACD) is a self-acting microprocessor-based data communication device designed and developed by Kankan Railway [5].The system consists of Loco ACD with a console (message display) for the driver (in each Loco Engine), Guard ACD with remote (fitted in Guard Van), Station ACD with console (fitted in Station Masters' Cabin), Manned and Unmanned Gates ACD with hooters and flashers (in each location) and Repeater ACDs (fitted at locations having obstructions in radio communication such as hilly areas) which work in concert to prevent the following kinds of collisions and accidents like-Head on collisions ,Rear end collisions ,Collisions due to derailment, Collisions at the level crossing gates .

III. The proposed system

The proposed Train Anti Collision System consists of a self-acting micro-controller[6] and two way Zig-Bee[5] based data communication system which works round-the-clock to avert train collisions. Thus enhances safety in train operations by providing a NON-SIGNAL additional safety overlay over the existing signaling system. The system operates without replacing any of the existing signaling 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, signaling Posts. The efficiency of the system is expected to be considerably increased as the proposed system takes inputs from the signal posts. 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 2 deal with the proposed system detailing the schematic diagram for various sub Modules [2]. Figure-3 shows overview of the proposed system. The proposed Train Anti Collision of a microcontroller and full duplex Zig-Bee-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 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, control stations to continuously monitor various signals arriving in the control center and taking decisions based on the received information. Zig-Bee 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', '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, and Railway signal posts, Stations, form an intelligent full-fledged eventuality detection and prevention. The proposed model makes use of Zig-Bee protocol [8] as a medium of transferring information.

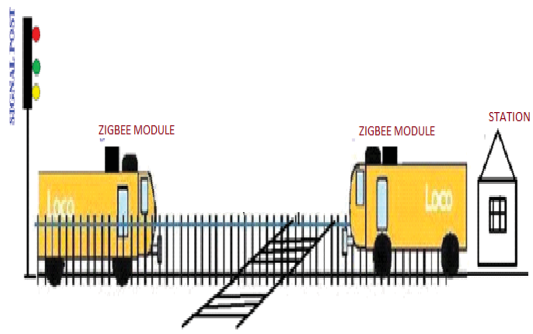
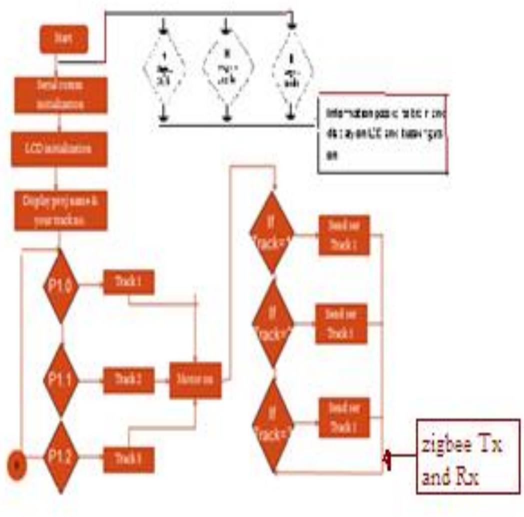


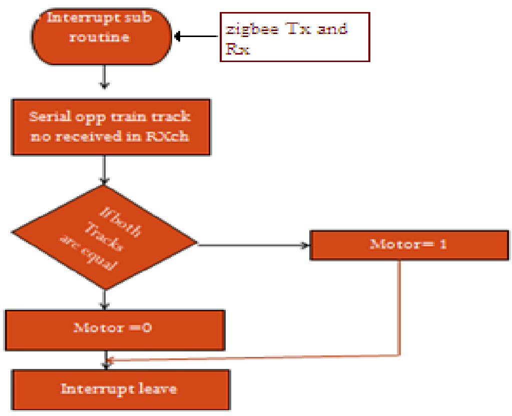
Figure-3 Overview of the proposed System

Flow chart of the proposed system



Transmitter section

In the transmitter section first the serial communication is initialized and the lcd display is initialized with the system name. then after it transmits the track number if any train searching for the same track number and for any rail breakages of the train if everything is correct then the motor starts running.



Receiver section

In the receiver module the same process takes place as that in the transmitter section up to the lcd initialization. Here this module receives if any train searching for the same track number if everything is correct then the engine starts running.

Whenever any connection failure between the bogie occurs, an intimation to train is given .The connection failure between any two corresponding bogies is sent to the microcontroller,which in turn gives the information to the LCD.The LCD displays the number of the corresponding bogie which is failed.

IV. Simulation and modeling

Traditionally circuit simulation has been a non –interactive affair. In the early days net list were prepared by hand,and output considered of reams of numbers.

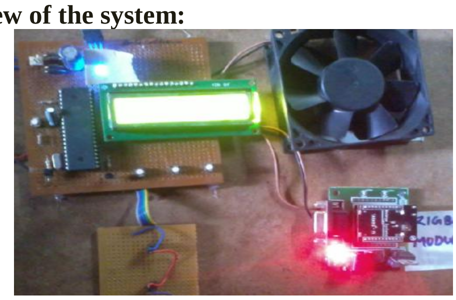
4.1 Proteus Simulation Software:

Proteus Virtual System Modeling (VSM) combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co simulation of complete micro-controller based designs. For the first time ever, it is possible to develop and test such designs before a physical prototype is constructed. This is possible because one can interact with the design using on screen indicators such as LED and LCD displays and actuators such as switches and buttons. The simulation takes place in real time (or near enough to it): a 300 MHz Pentium II can simulate a basic 8051 system clocking at over 12MHz. Proteus VSM also provides extensive debugging facilities including breakpoints, single stepping and variable display for both assembly code and high level language source.

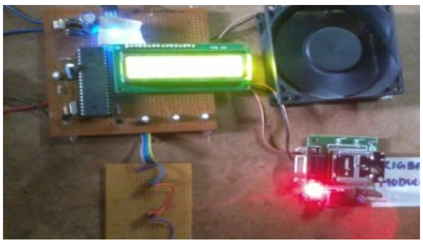
4.2Microcontroller Model functionality:

The core of any embedded system design is the micro-controller and the completeness of the model as well as its accuracy are therefore of primary importance. It should always be ensured that simulation models for micro-controllers not only support a peripheral that one wants to use but support the mode in which one wants to use the peripheral and to a satisfactory level of detail

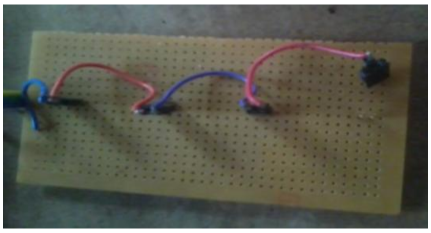
5. View of the system:



Two Trains coming on same track i.e zone 1and zone 2 at the same time.



Two Trains running on different tracks.



When the connection of compartments failed.

V. 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, and Control Center. Decisions are arrived at based on train to train communication and also with the existing railway signaling system which is made possible by the four independent sub modules. Results of testing the fabricated circuit are discussed.

In this model we have considered 8 km track separated by 1km zones because we have assumed that 1 km is a minimum safest distance to avoid collision between two trains. Here each of the 1 km zones contains pressure sensors placed under the track. In our system we use compression type pressure sensors. The minimum pressure to be sensed by a load cell or pressure sensor is 6 tones, because 6 tones is the minimum carriage weight of an empty carriage of goods and passenger trains as per Indian Railway norms. The minimum voltage sensed by pressure sensor is as ‘high’ as 0.8 volt. The different conditions under which the two trains run on the track with different relative position with respect to each other are considered in this work. Then each different condition has been simulated in software.Results of these cases are displayed below.

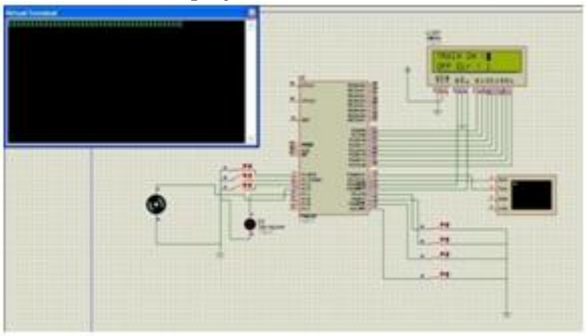


Figure-4. Two Trains coming on same track (zone 1&zone 2) at same time.

So that immediately an alarming signal has been generated to the railway control room, station, substation and grid control station to prevent this massive accident.

In the figure below, it is clear that the two trains running on same track. So at the output there is no possibility of collision, because the distance between two trains are running on track alternate zones. That's why the symbolic representation of engine as motor is stopped running.

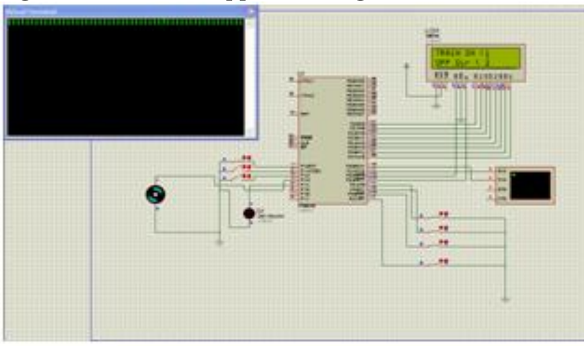


Figure-5 Two Trains running on different tracks.

The simulation model result show that whenever there is a chance of collision the system gives an output signal and applies the penalty air brake to stop the loco engine. This helps in avoiding collision by appropriate steps to be undertaken by the respective railway station. Whenever there is a no chance of collision due to the train being on different track. There is no output from the simulated system model.

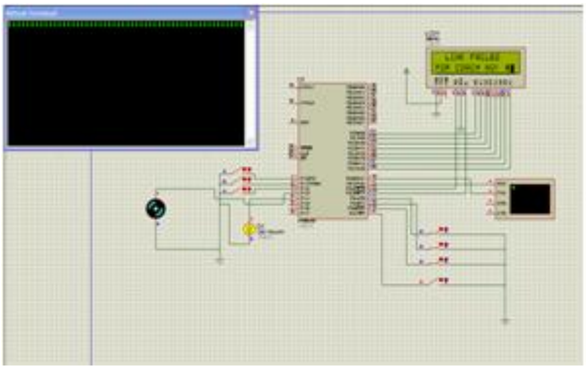


Figure-6: When the connection of compartments failed.

Figure shows the output when the connection between compartments failed and the yellow LED is taken for the representation of the buzzer. It raises an alarm whenever there is a link failure between compartments.

VI. Future scope

By using zigbee it covers up to 1km, whereas by using Wi-Fi we can cover over long distances. so that we can easily avoid the accidents and can have the safest mode of transportation.

VII. Conclusion

In this paper, a design for automatically averting train collisions have been designed and simulated. 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 barking. 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. While rail continues to be one of the safest modes of transportation, the overall safety has not significantly improved since the Railway Safety .Continuous improvement is important to achieving a better safety record. Certain accident categories have seen little improvement in accident rates over time, while others are worsening and have the potential to negatively affect public confidence in the railway system. Nonetheless, we also observed stronger safety records in certain areas and believe they are the result of sustained efforts to improve safety. Through this innovative technique of early sensing of any possible collision scenario and avoiding it thereof, we demonstrate that it is possible to improve the overall safety of the railway system in India. We believe that success depends on both the railway industry and the regulator working together to achieve that common goal.

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