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An Automated System to Mitigate Loss of Life at Unmanned Level Crossings

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Abstract

Every life is precious and is worth saving. This paper proposes the design and implementation of a system to mitigate the loss of life at unmanned railway level crossings. This system uses the advancements in Communication, Embedded Systems and Internet of Things to develop a real-time, early warning system for unmanned level crossings across India. The outcome of this work is to provide an audio- visual indication to the commuter warning about an approaching train. The need for such systems and its design implementation and feasibility is discussed in this paper.

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Keywords: early warning system; internet of things; cloud technologies; unmanned level crossings.

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1. Introduction

The number of deaths caused by accidents at unmanned railway level crossings is increasing at an alarming rate across different parts of India. The existing methods that are in place to mitigate such disasters are by building Railway Over Bridges (ROBs)[3] or by converting these crossings into manned level crossings. Although the traditional methods are effective, it involves big budgets and takes a long time to become fully operational.

Train accidents at level crossings have always been a cause of concern for Railways. In 2011-12[2,6,17], Indian railways recorded about 15,000 deaths. Experts say, almost 70% of these took place at Unmanned Level Crossings. The aim of this work targets in saving thousands of lives that are lost in such tragic incidents. The prototype presented in this paper is designed with the motto, "Every human Life is precious! Each life is worth saving! ".

The contents of this paper are organized as follows: in Section 2, a study is done on the lives lost at level crossings and the shortcomings involved with the traditional solutions that exists. In Section 3, an overall design of the proposed prototype is discussed which is followed by the actual development of the prototype that is discussed in section 4. The results from simulations and the implementation are discussed in section 5. In section 6 we discuss the future works and extensions possible with this prototype.

2. A Study on the Existing Eco-System

In India there are about 13,530[2] Unmanned Level crossings. While the Indian Railways does not divulge the actual number of deaths at unmanned level crossings, a rough calculation can help us understand the gravity of the situation. An accident at Level crossings is a universal issue. At least 6,000 people die at level crossings every year. In India, 61% of railway related fatalities are attributed to accidents at Unmanned Level Crossings as shown in fig.1. Nearly two thirds of the total number of Level crossing accidents occur at unmanned Level Crossings and this proportion has been increasing ever since.

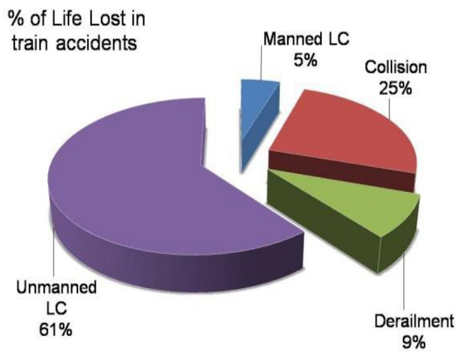

Fig.1. A chart showing the Loss of lives in train accidents (in percentage)

The current solutions proposed and implement to mitigate the loss of lives at Unmanned Level crossings is to build Railway over Bridges (R.O.B.) or by converting them to Manned Level crossings. These solutions bring with them a large overhead on financial, political and time constraints. For instance, the problem with R.O.B. is that it requires huge financial investment to build one and takes years to complete without any deadlocks. Consider this: Sixty crossings could not be closed despite commissioning of over bridges, due to technical difficulties and the costs involved. Ten thousand and five hundred lives a year—or even one for that matter—is too high a price to pay. Even people need to inculcate the seriousness about crossings to avoid these tragic accidents that are now occurring so frequently. The proposed prototype is a cost-effective solution and much easier-to-implement compared to the existing traditional methods. The time and financial overheads involved in designing and implementing this device is substantially lesser than building a R.O.B.

3. Proposed Solution

This work aims to develop a system of inter-connected devices that can warn commuters and possibly avert dreadful accidents at unmanned level crossings. The novelty lies in the simplicity of the design that makes it a cost-efficient system which can be effectively deployed across the country in a very short time. The system uses efficient algorithms and protocols like SPI (Serial Peripheral Interface) that saves power, thus improving the life span of each module. The different off-the-shelf components are connected to a single network, this results in an Internet of Things[5,10,12,13] eco-system. The reliability of the data acquired from the sensor nodes are shared in real-time, with a minimal security to prevent any loss in the data. An overview of the complete system is shown in fig.2(a). The warning to the commuters is given using alarms that operate in high frequency (very loud sound) for the audio. The visual warnings are given by using LED panels or a dense, focused laser beam.

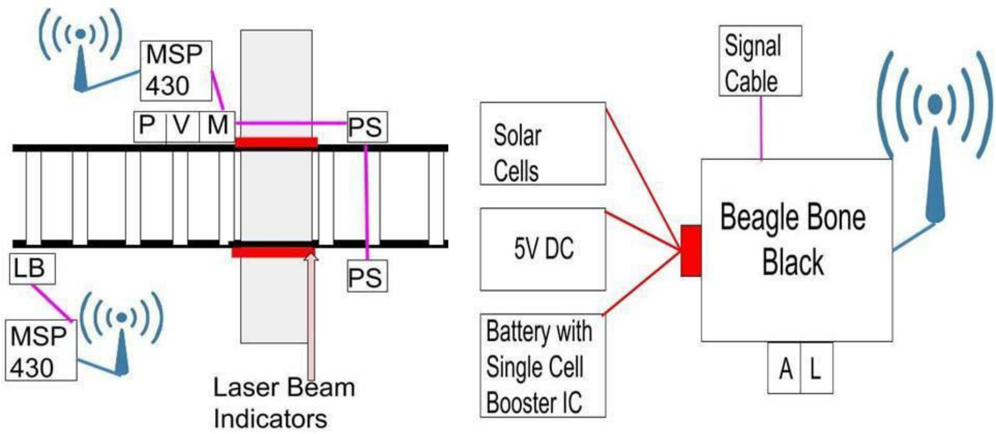

Fig.2(a).The complete design of the system with respect to the sensor nodes; (b) Design of the Device placed at the Unmanned Level Crossing.

The sensors that are used are pressure (P), vibration (V), magnetic (M) and proximity (PS) sensors respectively. The sensors are interfaced using a Texas Instruments' MSP30 Launchpad as the preferred micro controller. The sensors are supported by a thin laser beam (LB) that is passing between the two rails. The laser beam will be the first indicator to detect the train. Subsequently, the vibrations on the rails trigger the vibration sensor; the weight exerted on the tracks triggers the pressure sensor and magnetic sensor which senses the magnetic field produced when a train passes over it. The sensor nodes are interfaced with the Texas Instruments' CC2500 RF[8,9,11] Module, to facilitate wireless[1,4] communication between the sensor nodes and the master controller. The Beaglebone Black is configured as local cloud storage for the sensor data and the master controller. The Beaglebone boards will be placed at the level crossing and this board is also responsible for the control of the alarm and LED strips. The Beaglebone Black interacts with the Operations Center and reports regarding the health of sensor readings and nodes are sent periodically.

4. Implementation

In this section the development and implementation of the early-warning system is discussed in terms of configuring the hardware and software.

4.1. Hardware Implementation

The prototype is an integration of a two device one that is placed on the sides of the Track and the other on the level crossing. The system makes use of sensor inputs from the sensor nodes placed near the railway track and sounds an alarm in the event of a train approaching an unmanned level crossing. A Texas Instruments MSP430 micro-controller controls the sensors. The Beagle Bone monitors the sensor nodes to get details of the approaching train and identifies any malfunctions. The communication between the Beagle Bone and MSP 430 micro controllers is encrypted using XXTEA to ensure reliability of data.

The device shown in fig.2(b) will be placed at the intersection of the road and rail - unmanned level crossing. The design features a complementing set of alternative power sources to be used in case of a power failure. The commuters are warned of an approaching train by sounding an alarm (A) and signalling using LED Strip or a Laser beam (L). The intensity of the alarm sound and the brightness of the LED Strip increases as the train approaches closer to the crossing. The sensor node as shown in fig 3 is developed on the MSP430 controllers that control a cluster of like Vibration(V), Magnetic (M), Pressure (P) and Proximity (PS) Sensors. These sensors are supported by a thin laser beam (LB) that is passing between the two rails. The laser beam will be the first indicator to detect the train. Subsequently, the readings from the sensors are used to indicate and confirm if the train has passed the crossing completely. The sensor nodes are interfaced Texas Instruments' CC2500 Wireless Modules for wireless communication to Beaglebone Black. The CC2500is configured to work in SPI (Serial Peripheral Interface) mode which makes the device work for long hours on battery, thus improving its efficiency.

4.2. Software Implementation

This section gives the details of the software implementation. The algorithm or pseudo steps are shown below.

Working of an End-Device - MSPEXP430 Launchpad and MSP430 ez430RF2500

1. Read the raw sensor values and store into a variable.
2. Set desired precision for the values.
3. Create a packet with device Id and Sensor values
4. Convert it into a single string – (for ease of processing).
5. Encrypt the string with XXTEA algorithm.
6. Send the packet Via UART
7. Receive the data from serial (UART)
8. Store the received character in a buffer
9. Send the contents of the buffer using SPI via CC2500
10. Sleep for 150 ms.

Working of the Access Point - MSP430 ez430RF2500 with Beaglebone Black

1. Buffer the received packet
2. Send the packet to Beagle Bone Black via UART
3. Sleep for 150 ms.
4. Read the packet from the serial port in Beaglebone Black
5. Decrypt the packet to a string of plain text.
6. Process the plain text to extract individual sensor values
7. Append the sensor values to a csv file or a database
8. Sleep for 100 ms.

4.3. Data Acquisition & Analysis of Hardware Health

The data acquired from the sensor nodes are pushed to the cloud created on the Beaglebone Black and is uploaded every 10 seconds. The data processing is done using a python script that appends the sensor data to a local data base and a comma separated value (csv) file, maintained on the Beaglebone Black. The outputs of the processed data is a graph - generated using the Google Charts API. The csv file can be accessed only by the administrator or the authorized personnel in the network. The information extracted from the csv file includes details of the sensor nodes, its corresponding sensor values and a timestamp, each in separate columns. The sensor values are the measurements from the pressure, vibration and magnetic sensors. System tests are currently done in laboratory environment to analyze the performance of the proposed system and also working on ways to reduce the cost and maintenance. The following are the scenarios which require the administrator to take the decisions:

1. A sensor failure is indicated when a null value is sensed for a consistent time period. An alert message is passed to the administrator by the End Device through Beaglebone Black.

2. When the access point does not receive data from a sensor for a long time (time in terms of hours).An alert message is passed to the administrator by Beaglebone Black.

5. Results

The data that is available at the sensor nodes (P, V, and M) is encrypted and transmitted as packet. The received packet is decrypted at Beaglebone Black. The encryption is done using XXTEA, because it has a low resource overhead which is more suitable for embedded devices. The encryption ensures data reliability and security from intruder attacks during communication. The process of encryption and decryption in the sensor nodes is shown in figure 3(a). The packet is received in plain text by Beagle Bone Black is parsed into variables for storing the sensor node's Id, timestamp and sensor data. The parsed data are then uploaded to a cloud server created using Owncloud. The local database containing the sensor data is represented as graphs makes both maintenance and monitoring of the system administrator-friendly.

The data acquired from the various sensor nodes populate a csv file that is maintained on the Beaglebone Black. This file can be used for verifying the effectiveness of the system and can also be used as a real-time data set thus collected can be used in the following ways: to estimate traffic patterns, speed limit imposing can be done. The csv file thus generated is shown in figure 3(b). It is to note that when the proximity of the train to a sensor node is low, the train is near and both the audio and visual alarms are triggered.

Data at the sensor Nodes (Sender)		Data at BeagleBone Black (Receiver)	
Actual Data	Sent Data	Receive d Data	Actual Data
*4@61$126 %307^1017#	Ik(ƒ{"r+ Ý Ïk(ƒ{"r+	Ik(ƒ{"r+ Ý Ïk(ƒ{"r+	*4@61$126 %307^1017#
*1@237$304 %426^691#	Z‡R¯□ Wûñ^Xš U Ž‡R¯□ Wûñ^Xš	Z‡R¯□ Wûñ^Xš U Ž‡R¯□ Wûñ^Xš	*1@237$304 %426^691#
*3@563$513 %580^114#	¿íE1ð["ɾ ‹å ¿íÉ1ð["ɾ ‹	¿íE1ð["ɾ ‹å ¿íÉ1ð["ɾ ‹	*3@563$513 %580^114#

	A	B	C	D	E	F
1	timestamp	deviceid	pressure	vibration	magnetic	proximity
2	10/25/2015 11:24:30	4	61	126	307	1017
3	10/25/2015 11:24:31	1	237	304	426	691
4	10/25/2015 11:24:32	3	563	513	580	114
5	10/25/2015 11:24:33	4	793	981	937	274
6	10/25/2015 11:24:34	1	1021	978	925	219
7	10/25/2015 11:24:35	3	381	389	238	670
8	10/25/2015 11:24:36	4	660	762	808	314
9	10/25/2015 11:24:37	2	993	985	912	37
10	10/25/2015 11:24:38	1	59	89	356	896
11	10/25/2015 11:24:39	3	443	337	357	701
12	10/25/2015 11:24:41	3	217	84	263	763
13	10/25/2015 11:24:42	1	791	944	785	244
14	10/25/2015 11:24:43	1	622	344	457	1001
15	10/25/2015 11:24:44	3	856	750	846	343
16	10/25/2015 11:24:45	3	632	919	932	153
17	10/25/2015 11:24:46	2	825	969	869	397
18	10/25/2015 11:24:47	2	92	370	89	1014

Fig.3 (a). Securing data communications between sensor nodes and access points; (b) A screenshot of the csv file maintained by Beaglebone black with data from the sensor nodes

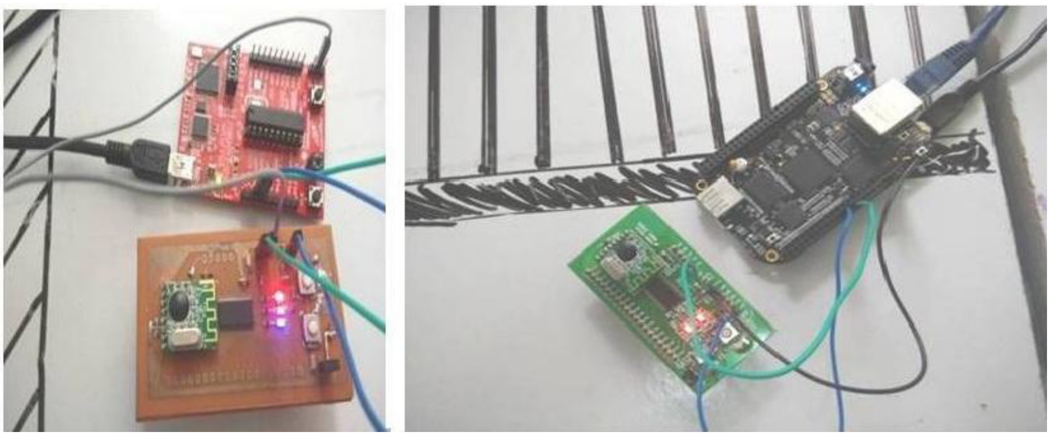

Fig.4 (a). The End Device or the Sensor node developed using MSP430 Launchpad and CC2500 RF Module (b). The decision hub developed using Beagle Bone Black and CC2500 RF module.

The prototype is tested under various laboratory conditions to test the endurance and performance. The tests include a stress test and performance test. The hardware components namely the sensor node and the control unit based on Beaglebone Black are shown in Fig 4 (a) and fig 4(b).

6. Conclusion

The prototype of an early warning system for unmanned level crossings is discussed in this paper. The test conducted in laboratory environment indicates the system works perfectly with low energy consumption. The data thus collected in the csv file will be used to model a prediction algorithm that can understand traffic patterns and suggest suitable alterations to the running time and establish block-section limits to prevent accidents. The proposed design can also be deployed in areas of man-animal conflicts like the Western Ghats. The system will be modified to sense the presence of any animal on the track, and a caution signal will be broadcasted to the trains in the vicinity. Also, an effective communication standard is being identified to minimize the delay in communication between the sensor nodes and the decision hub.

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