Railway Warning and Control Systems

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*Abstract***—** *This paper presents overall system description of the implemented system on the sensor network based railway warning and control system. With the main objective of providing the protection to the public at the unmanned railway crossings this system is implemented. In order to implement a railway warning in each and every railway crossing this system is developed in economic way. The sensors at the sensor node which is kept away from the railway crossing detect the train and the signal is send to the centre node via RF transceivers to actuate the warning lights and the siren alarm at the centre node.*

Keywords— *Railway Crossing, Ultrasonic Sensor, Wireless Communication*

I. INTRODUCTION

In many parts of rural areas in Sri Lanka, it is common for roads carrying motor vehicular traffic to cross railroad tracks without gates, warning lights, or signalling means being provided to warn the motorist of oncoming trains. In such circumstances at these unguarded crossings, it is incumbent upon the motorist to approach the crossing carefully, to look and to listen for approaching trains, and to proceed only with assured clearance before any approaching trains. When careful, alert motorists approach the unguarded crossing "self-help" philosophy works satisfactorily. However, this system contains many traps for the unwary, careless, and distracted or impaired motorist, or motorists approaching the railroad crossing under conditions of reduced visibility such as fog, heavy rain etc.

Frequent users of such an unguarded railroad crossing easily become careless about attentively looking for approaching trains. Seldom-used rail lines easily mislead the motorist into false security about the probability of an approaching train. The infrequent user of a particular unguarded railroad crossing is likewise subject to certain dangers. Lacking descending gates, bells, warning lights or other means of drawing the motorists attention to the crossing, the inattentive motorist not familiar with the particular road may not notice the approaching rail crossing until it is too late to take prudent safety measures with consideration of the speed of his or her vehicle.

During periods of darkness, inclement weather, or any condition of reduced visibility, it becomes that much more difficult for the motorist to observe and then identify the unexpected railroad crossing. The motorist not expecting a rail crossing may be slow to detect and identify the crossing, slow to react in safely slowing the vehicle, and slow to look and listen for approaching trains. Once again, the infrequency of use of the particular railroad by trains almost always rescues the inattentive motorist from the consequences of his or her negligence. However, the results are serious indeed when the unmindful motorist encounters the infrequent approaching train.

I. METHODOLOGY

In our design there can be found three nodes. Two sensor nodes are placed either sides of the railway crossing. These sensor nodes consist of two ultrasonic sensors and one vibration sensor to detect the approaching train. When a train arrives near the crossing the sensor node which is kept 500 m away from the crossing detects the train and transmits to the control node with the use of radio frequency wireless transmission. Then the control node actuates according to the signal that gets from the sensor node. The control node consists of alarm and warning lights. If the train arrives near the crossing both these warnings are actuated to inform the public that a train is coming. The simplified block diagram which shows the functionality of the system is shown in the FIGURE 1.

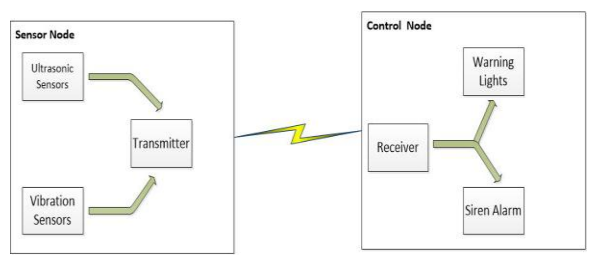

FIGURE 1: Block Diagram of the network

II. SYSTEM DESIGN

A Sensor Node

Mainly the sensor network comprises with two types of sensors which have been used by placing them in different levels. Ultrasonic sensors and microphone have been used for the detection of approaching train. As illustrated previously sensor nodes are connected with one control node which is mounted near the railway crossing.

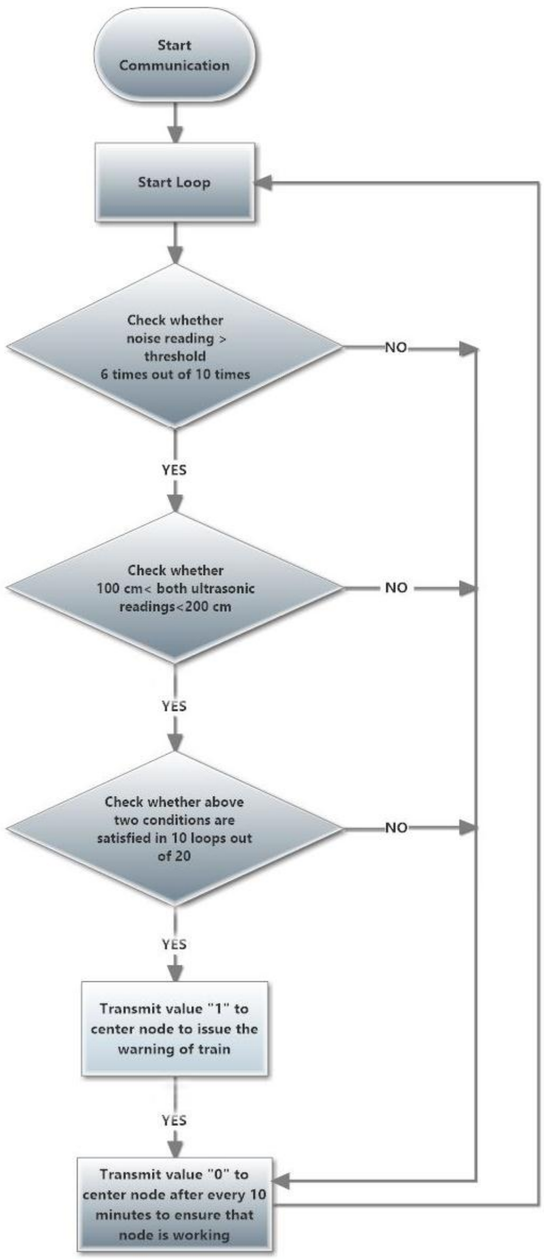

FIGURE 2: Algorithm of the sensor node

As illustrated previously sensor nodes are connected with one control node which is mounted near the railway crossing. The sensors which are suitable for design are selected according to our criterion. The design strategy of sensor node is shown in FIGURE 2.

Algorithm we used to detect the train is as above. Ultrasonic sensors which read the maximum distance as 450cm are set to output HIGH state as the detected distance is less than 300cm. Because the sensor node is kept near the railway track and when the train passes the sensed distance is less than 300cm. For the worst case of this is the making the output as High by both sensors. Although the sensors are recognizing the distance from two levels they both can be HIGH simultaneously. Hence we have used microphone as the sound level generated by the train cannot be given by any other physical component. If both the sensor values and microphone values are HIGH the logic 1 is transmitted to the control node. When the control unit grasps this signal it knows that a train is coming and warning for the public is given by lamps and siren alarms.

1) Ultrasonic Sensors

Two ultrasonic sensors are used to detect the travelling train. They are mounted on two different levels of the sensor node. The two sensors employ commercial 40 kHz piezoelectric resonant transducers to generate the ultrasonic pulse. Such transducers are readily available in waterproof containers for a low cost. The human ear can hear sound frequency around 20HZ - 20KHZ, and ultrasonic is the sound wave beyond the human ability of 20KHZ [1]. We have used HC SR044 ultrasonic module for the design of our sensor network. Actual placement of the sensor node is shown in the FIGURE 3.

As the warning system should be implemented with lowest uncertainty the ultrasonic sensors provide this requirement. The SIL 4 safety level [5] have to be satisfied by the signalling system. The sensor has been designed in order to satisfy typical requirements in the automotive field: measured distance in the range of 0.1 m to 0.3 m and standard uncertainty of 1 mm in the temperature range of 00 C to 400 C. Measured distance up to 1 m and in a wider temperature ranges are possible even though at higher uncertainty. We do not need to detect much higher distance and in Sri Lanka the temperature does not rise more than 400 C. There are several other factors which affect the sensitivity of the ultrasonic sensor.

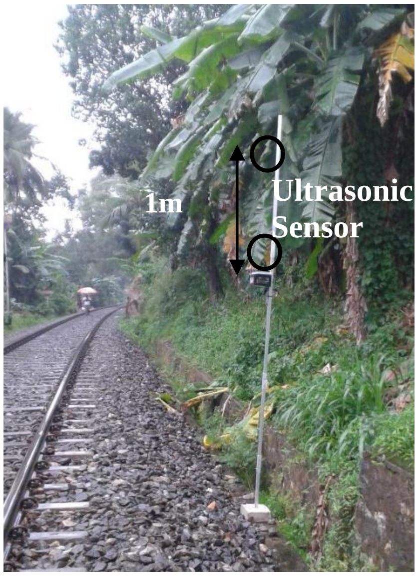

FIGURE 3: Block Diagram of the network

2) Microphone

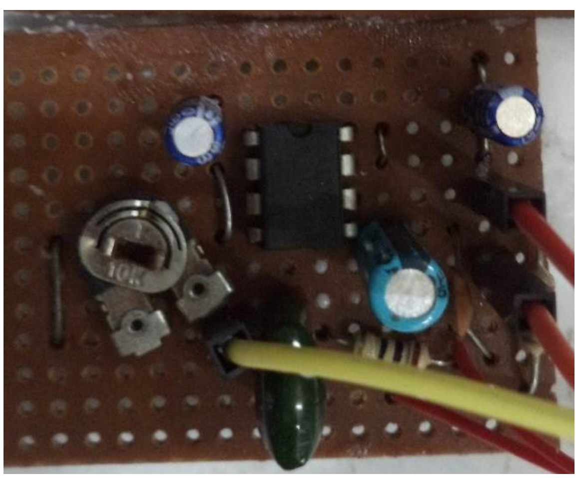

FIGURE 4: Microphone amplifier circuit

We have noticed that there is a relationship among voltage value and the amplitude of the sound generated by the train. When the train arrives near the sensor the potential and sound amplitude both are increasing. i.e the amplitude of the sound generated by the train is proportional to the distance. Therefore both vibration and sound can be used to detect the train and gives the signal to the public about the arriving train. So we have chosen sound to detect the train as it approaches the sensor node.

As the train generate loud noise as it travels along the track we have decided to use the sound as the detecting factor of train. In here, we will go over how to connect a microphone to an arduino so that the arduino can detect whether there is sound in the environment or not. The circuit shown in the FIGURE 4. is only capable of detecting whether there is sound in the environment or not. The microphone simply serves to detect whether there is sound. The arduino also has the capability of measuring the level of the sound, so that only sounds above threshold can actuate the signals.

3) Wireless Transceiver Unit

The approximate breaking distance of the train is considered as 210 m. Therefore the sensor node is located about 300 m away from the railway crossing. The train approaching should be transmitted to the control node for activate the warnings for the public. We have used NRF24L01+pa+lna as the transceiver module which is a long distance radio frequency range operating device .Open transmission distance up to over 1000 m at 250kbps. As we have to transmit signal of the train approaching from at least 500 m away from the control node we have selected this module. But we have to consider about the noise signals which make bad influence on the transmitting signal.

B) Control/Centre Node

Control unit compromises with warning lights and siren alarm to give the warning to the public. The block diagram of the operation of control node is shown in FIGURE 6. The signal from the sensor node has reach the control node it starts to warn that a train is coming. Continuously control node sense whether there is a communication between two nodes and when a signal is received it turn on the warning lights and siren.

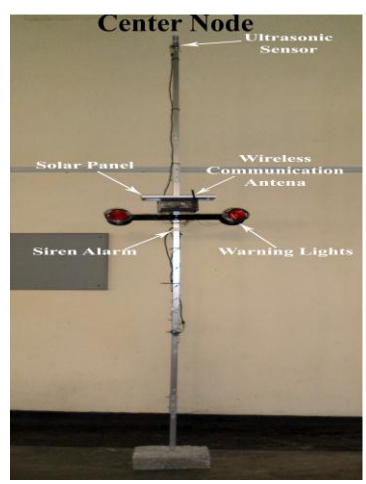

FIGURE 5: Implemented centre node

C. Power Management Unit

A solar power supply system used in wireless sensor node includes a power supply module having a solar cell set and a rechargeable battery set and a power management unit. 9V solar cell is placed so as it received sun light in maximum number of hours in all over the day. Rechargeable battery recharged by solar cells. When the voltage of the solar panel do not satisfy storage battery capacity then two or more same solar panels can be used together in series. In order to speed up the rate of charge, two or more same solar panels can be used together in parallel connection. Under bright sunlight, the battery bank charged while supplying power to the sensor nodes directly.

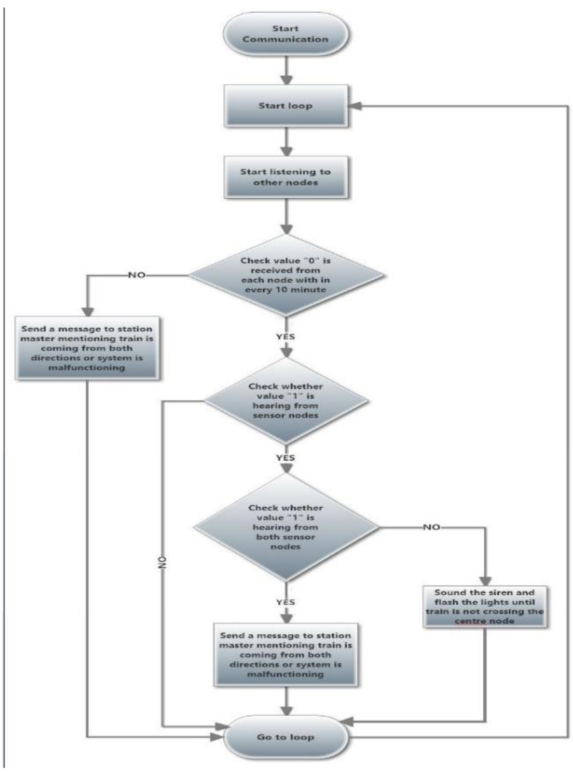

FIGURE 6: Algorithm of the centre node

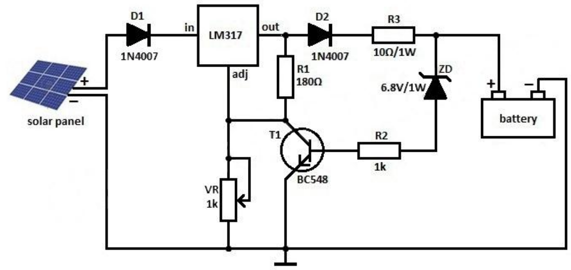

FIGURE 7: Power management circuit

When sunlight fail to power up the sensor nodes the power supply by battery while discharging the battery. To swing between two power sources the power management system is used.

Power management unit comprises a microprocessor, a voltage detection device that detects the voltage level of the solar cell set and the rechargeable battery set, an idle power supply module and a power switching module controllable by the microprocessor to switch between the solar cell set and the rechargeable battery set [4]. Power supply module provides battery power supply from the solar cell set or the rechargeable battery set to the sensor node and thereby saving power consumption. The circuit which is shown FIGURE 7 uses a 9 volt solar panel and a variable voltage regulator IC LM 317. The solar panel consists of solar cells each rated at 1.2 volts. 9 volt DC is available from the panel to charge the battery. Charging current passes through D1 to the voltage regulator IC LM 317. By adjusting its adjust pin, output voltage and current can be regulated.

Variable resistor is placed between the adjust pin and ground to provide an output voltage of 9 volts to the battery. Resistor R3 Restrict the charging current and diode D2 prevents discharge of current from the battery.

Transistor (T1) and zenor diode act as a cut switch when the battery is full. Normally T1 is and battery gets charging current. When the terminal voltage of the battery rises above 6.8 volts, zenor conducts and provides base current to T1. It then turns on grounding the output of LM317 to stop charging.

III. ANALYSIS OF DATA

The wave propagation was sensed by microphone and recorded with the help of analysing software and recorded data is presented in following figures. It shows the status of the train before the measurement point.

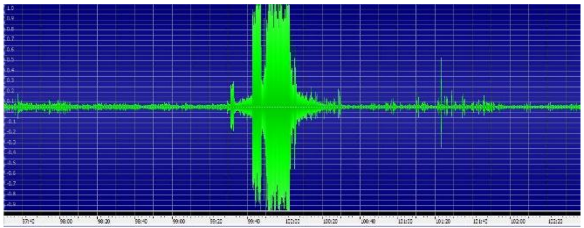

FIGURE 8: Sound Levels of the Approaching Train at 06.55 am

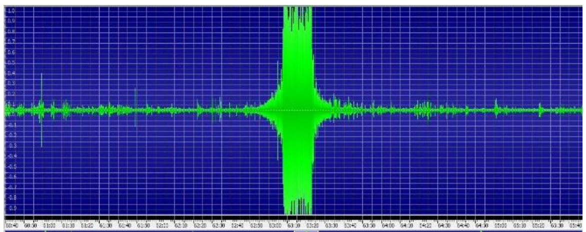

FIGURE 9: Sound Levels of the Approaching Train at 07.25 am

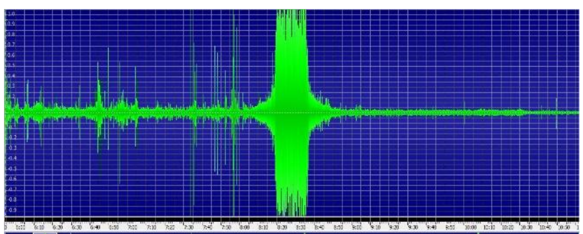

FIGURE 10: Sound Levels of the Approaching Train at 08.36am

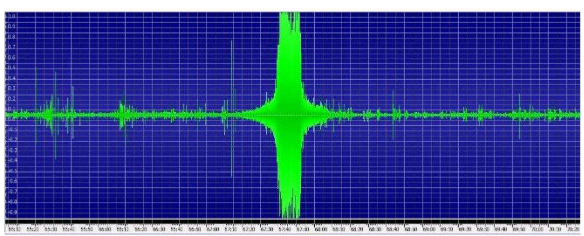

FIGURE 11: Sound Levels of the Approaching Train at 09.06 am

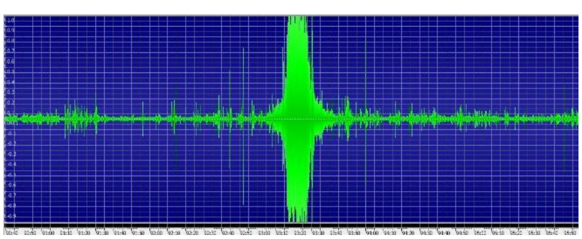

FIGURE 12: Sound Levels of the Approaching Train at 09.30 am

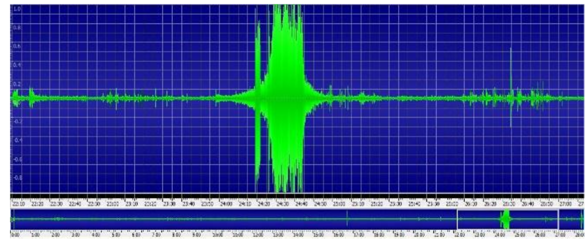

FIGURE 13: Sound Levels of the Approaching Train at 11.00 am

These figures indicate noises around the track is lower than the train generated sound and it shows the status of the train before the measurement point and after that train arrives near the measurement point the spectrogram clearly shows a large deviation. The sound generated from the train is so enormous and it is clear from the recorded data that wave propagation is

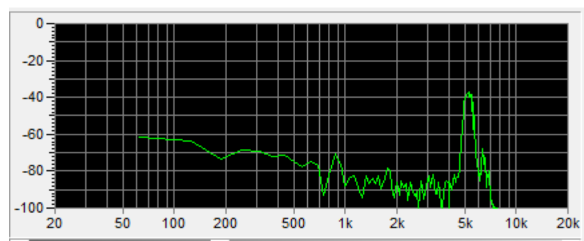

FIGURE 14. Spectrum Analysis of the Sound Output of the microphone

possible inside the rails and magnitude and frequency of that wave is increasing with the arrival of train at measurement point and after crossing of train sudden reduction in both were observed.

The spectrum analysis of the recorded data is done to get an insight about the behavior of the signals. Several of GoldWave's control visuals convert sounds into a range of frequency bands using a radix-2 fast Fourier transform (FFT) algorithm. The spectrum analysis yields some interesting facts about the signals frequency [5] the graphs shown in FIGURE 14. And it was taken from the microphone which was placed on the sensor node. Here the peak amplitude is greater than the other environmental sounds.

It is clearly shown in figure that the maximum frequency component is at 1.8 kHz and the maximum amplitude of the signals is about -38 dB. And according to the recording that we have obtained that is the time when the train has come. When train arrives near the sensor amplitude value increase drastically as shown in the FIGURE 14.

IV. FURTHER DEVELOPMENT

There is much work to be done in the future both on our portion and for the overall project. Also some additional components can be introduced in order to enhance the operational accuracy of the product.

More powerful ultrasonic sensors can be further used to analyse the values of failures and successes of the design and indicate them to the relevant parties. And also for graded crossings we can use these kind of sensors too. We have implemented the system only at railway crossing. But we can place these sensor nodes at certain distance to locate the train. This will help to find out where the train is. And also we can control accidents of trains by detecting the trains before two trains enters to same block by using these sensor nodes. Because we can send the locations of the trains to the station master to stop any collision if there any.

This system can be used for other concepts such as defect analysis of the railway track with some modifications to proposed design.

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