Fish Plate Security Using IR Sensors with RFID & IEEE 802.15.4 modelled Wireless Mesh Networking

Samarth Sharma
Indian Institute of Technology
Kharagpur India - 721302

Samaresh Choudhary
Pervcom Consulting Pvt. Ltd.
Kolkata India - 700068

Somprakash Bandyopadhyay
Indian Institute of Management
Calcutta
Kolkata India – 700104

Abstract

Indian Railways has one of the largest and busiest rail networks in the world, transporting over 18 million passengers and more than 2 million tonnes of freight daily. Hence, the security of Indian railways becomes indispensible. The illegal removal of fish plates from the rail line accounts for the large number of train accidents in India. Therefore, in the following paper we propose an intelligent system which continuously monitors the fish plates in the rail line and cautions the user in case of infringement.

The objective of our work is to develop a system for continuous monitoring of fish plates and immediate signalling on its removal. We use Real time Sensing System (RTSS) for the purpose. The system will consist of a sensing sub-system and a wireless network for communicating the information gathered by the sensing sub-system. The sensing system consists of a simple InfraRed sensor circuit to detect removal of fish plate. The information gathered by the IR sensors will be communicated to the base station using Radio Frequency Identification Technology and IEEE 802.15.4 modelled wireless communication standard. Our proposed system can be easily deployed by a company to secure their private rail lines for transportation of raw materials. To the best of the authors' knowledge, this is the first work developing a fish plate security system using Active RFID, IEEE 802.15.4 and IR sensors.

Keywords

RFID, IEEE 802.15.4, IR sensors, Fish Plate.

Introduction

Indian Railways carries over 18 million passengers & 2 million tones of freight everyday. A lot of industries depend on railways for the transportation of goods and raw materials. Hence in such a case, security of trains and rails on which they run becomes very important. In recent years, many passenger and goods train have derailed due to damages in rails of which missing fish plates accounts for the maximum number of such cases. In rail terminology, a **fishplate** or **joint bar** is a metal bar that is bolted to the ends of two rails to join them together in a track. Fish plates are made up of metals which have high market value. People illegally remove fish plates for monetary benefits. Various terrorist outfits have also been involved in such illegal activities. Maoists in Chhattisgarh and Andhra Pradesh have resolved to such techniques for disrupting public properties.

Fig 1. A Fish Plate with suitable position of sensors

Various measures have already been taken in the case of train security. Modern communication

technologies are being used for better signalling system. However, not many steps are being taken in the field of security of rails. The basic motive of our work is to secure the fish plates and prevent their illegal removal. We make use of Real Time Sensing System for the fish plate security. **Real-Time Sensing System** is a **sensor network based solution** for monitoring indoor as well as outdoor environment. The solution allows the user to monitor indoor air quality, outdoor climatological conditions, detect smoke, fire and presence of poisonous gases in the indoor environment using wireless sensors. Here we use it to 'sense' the removal of an object from its location. The system ensures immediate response in case of intrusion, so that proper steps can be taken with immediate effect and rail accidents can be prevented. The system will comprise of a sensor fitted on both sides of the fish plate, RFID tags beneath the rail lines and routers on the electric poles. The information gathered by the sensors and tags will be communicated to the base stations through multiple hops of routers. The sensors and tags will be powered by solar cells and batteries. Various sensors can be used for the purpose; IR sensors, micro-switches, etc. However, we have chosen IR sensors for the purpose because of their low cost and greater efficiency. Many industries having private rail lines for transportation of goods have shown interest in rail security. Our proposed method of fish plate security can be readily utilised by these firms.

Wireless personal Area Network

A personal area network [PAN] is a computer network used for communication among computer devices (including telephones and personal digital assistants) close to one's person. PANs can be used for communication among the personal devices themselves (intrapersonal communication), or for connecting to a higher level network and the Internet. A WPAN (wireless personal area network) is a personal area network - a network for interconnecting devices centered around an individual person's workspace - in which the connections are wireless. Typically, a wireless personal area network uses some technology that permits communication within about 10 meters . A wireless personal area network (WPAN) can also be made possible with network technologies such as IrDA , Bluetooth , UWB, Z-Wave and ZigBee.

A key concept in WPAN technology is known as plugging in. In the ideal scenario, when any two WPAN-equipped devices come into close proximity (within several meters of each other) or within a few kilometres of a central server, they can communicate as if connected by a cable. Another important feature is the ability of each device to lock out other devices selectively, preventing needless interference or unauthorized access to information. Proposed operating frequencies are around 2.4 GHz in digital modes. Our system makes use of Zigbee for the communication purpose.

Introduction to RFID

Radio-frequency identification (**RFID**) is the use of an object (typically referred to as an RFID tag) applied to or incorporated into a product, animal, or person for the purpose of identification and tracking using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader. There are generally two types of RFID tags: active RFID tags, which contain a battery and can transmit signals autonomously, and passive RFID tags, which have no battery and require an external source to provoke signal transmission. Here in our system we make use of active RFID integrated with IEEE 802.15.4 modelled wireless networking.

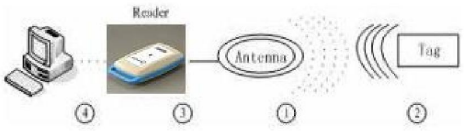

Fig.2. Work process of Radio Frequency Identification Technology

Introduction to Active RFID based integrated tracking and sensing system

1. Active RFID:

RFID system consists of tag, reader, and antenna. Tag which is attached to the object consists of coupling components and chips, and tag has a unique electronic coding. Reader identified tags with location information without contacting and it has two types—handled and fixed reader. The data received from tags transmits to Data Processing Unit. Antenna is a component that transmits radio signal between tags and readers. The system principle is as follows: 1) reader transmits a carrier signal; 2) tags in the field of reader antenna

produce electromagnetic power and transmit information to readers; 3) reader receives the signal and decoding; 4) the computer receives the data and performs data processing.

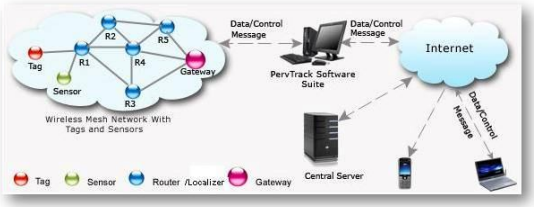

Fig.3. Structure of Wireless Mesh Network based on IEEE 802.15.4

2. IEEE 802.15.4/Zigbee based wireless communication architecture

IEEE 802.15.4/Zigbee is set of protocol specifying standards for Wireless Personal Area Networks. They provide best support for low cost, low power wireless mesh network and provide longer battery life but less data transfer rates. Main objectives of such communication system is ease of installation, reliable data transfer, short range operation, longer battery live while maintaining a simple and flexible protocol. It also supports Wireless Mesh Networking, which sustains signal strength by breaking longer distances in series of shorter hops. Intermediate nodes thus boost signal and perform further forwarding. Its self forming, self healing and self organization characteristics make communication system more reliable.

Infra Red Proximity Sensors

A **sensor** is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. Infra red sensors measure the intensity of infra red beams in the vicinity and convert it into electric signal. An IR sensor module consists of two parts – IR transmitter and IR receiver. IR transmitter transmits the IR beam of a particular frequency. Again, it's a forward biased LED which on passing current gives off an IR beam. IR receiver is a sensor which senses the presence of an IR beam. It is a reverse biased diode. It can then be connected to an oscilloscope or buzzer for us to detect an intrusion. The 3 pin IR sensor contains a resistor which enables it to receive IR rays of particular frequency only. This way it helps us in eradicating the unwanted noise. The IR transmitter and receiver pair is available in market in under Rs 10, which makes the proposed system cheap.

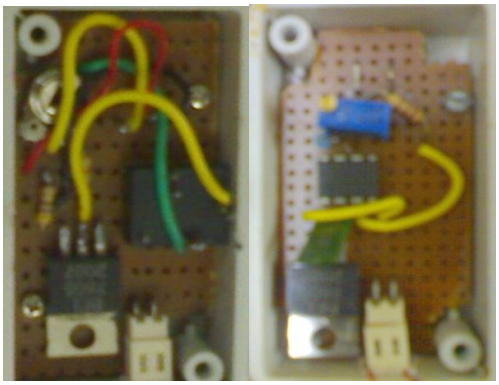

Fig. 4 IR sensors and receivers

Principle

IR LED emits infrared radiation in all direction. We can also make the beam directed, by covering it with black sheet. When photons are incident on reverse biased junction of IR sensor, electron-hole pairs are generated, which results in reverse leakage current. Amount of electron-hole pairs generated depends on intensity of incident IR radiation. More intense radiation results in more reverse leakage current. This current can be passed through a resistor so as to get proportional voltage. Thus as intensity of incident rays varies, voltage across resistor will vary accordingly. This voltage can then be given to OPAMP based comparator. Output of the comparator can be read by microcontroller.

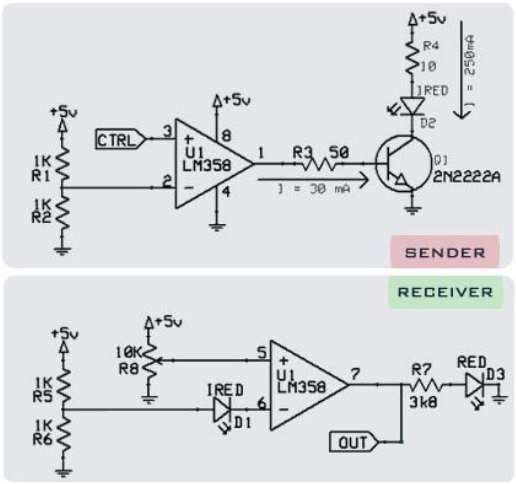

Fig 5 – Simple Transmitter and Receiver Circuit

Statement of System

We propose a system for continuous monitoring of fish plates in a railroad. The system after installation will be able to ensure immediate

response in case of removal of fish plate. It will consist of following parts – 1) IR sensor module, 2) Active RFID and IEEE 802.15.4 based wireless mesh network, 3) Power system for powering RFID tags and sensors. The power system will consist of a solar panel with a battery attached parallely.

1. IR Sensor module

IR transmitter and receiver will be attached on the both ends of the fish plate. The IR transmitter has to be designed for a high range, to make it more efficient. Hence pulsed IR will be used. This is a delicate task, as we need to send pulses of IR instead of constant IR emission. The duty cycle of the pulses turning the LED ON and OFF have to be calculated with precision, so that the average current flowing into the LED never exceeds the LED's maximum DC current (or 10mA as a standard safe value). The duty cycle is the ratio between the ON duration of the pulse and the total period. A low duty cycle will enable us to inject in the LED high instantaneous currents while shutting it OFF for enough time to cool down from the previous cycle. LM555 timer will be used for creating pulsed IR beams. The frequency which we have used for the purpose is 40 KHz. The OpAmp is used in the transmitter circuit to provide voltage buffer and also enable any kind of device (LM555 timer or any other microcontroller) for controlling the sensor. The transmitter circuit is shown in the above circuit.

The IR sensor consists of 3 pin IR receiver with OpAmp LM358. The OpAmp is again used as a comparator for measuring the voltage drop across the LED. The op-amp has 2 input, the positive input, and the negative input. If the positive input's voltage is higher than the negative input's voltage, the output goes High (5v, given the supply voltage in the schematic), otherwise, if the positive input's voltage is lower than the negative input's voltage, then the output of the Op-Amp goes to Low (0V). It doesn't matter how big the difference between the positive and negative inputs is, even a 0.0001 volts difference will be detected, and the output will swing to 0v or 5v according to which input has a higher voltage.

The sensor modules can be easily welded on the rails. (See the figure). Once the modules are installed, there are 2 ways in which fish plate removal can be detected. In the first way, the transmitter will be placed such that IR beam is continuously blocked by fish plates. Hence, whenever fish plate is removed the IR rays from transmitter will be detected by the sensor and the information will be rallied to the tags beneath the rails. In the second way, the transmitter will be placed such that it is just over the front surface of the fish plate so that IR rays from it are continuously detected by the IR sensors. Hence, whenever the fish plate is removed, it will block the rays and again the information will be signalled to the tags.

2. Wireless routing of the Information

We have chosen IEEE 802.15.4/Zigbee based wireless mesh network as the channel for communicating the information to a remote station. We use IEEE 802.15.4 based low-power wireless mesh network of tags, sensors, localizers/Routers and gateway to capture the identity and status of tagged objects. Tags, routers and gateways are all low-power IEEE 802.15.4 compliant active RF devices. The routers are arranged in a networking topology called “mesh”. Mesh network is a type of network where each node can communicate with multiple other nodes thus enabling better overall connectivity than in the traditional hub-and-spoke or star topologies. Wireless Active Localizers/Routers are placed at strategic locations around the sensing zone forming a wireless mesh network that serves as a wireless backbone to carry sensor data in multi-hop to the remote host system. The location of a sensor is determined in terms of the location of the nearest Localizer to that corresponding sensor. The location information can also be visible anytime from any web-enabled machine over the Internet. In our case, the routers can be placed on the signal posts on both sides of the tracks. Once, the information is sent to one of the routers, it will enter the mesh and the information will be automatically rallied to the remote station. Since routers are placed in mesh topology, failure of any router will not affect the communication process.

Integrated GSM Module – GSM (Global System for Mobile communications: originally from Groupe Spécial Mobile) is the most popular standard for mobile phones in the world. Most 2G GSM networks operate in the 900 MHz or 1800 MHz bands. A readily available GSM module helps us to use this cheap technology in our system.

The whole system can be integrated with GSM module to make the process of immediate response more effective. The access control devices can communicate with servers and security staff through SMS messaging. Complete log of the activity is available at the head-office Server instantly without any wiring involved and device can instantly alert security personnel on their mobile phone in case of any problem. The module will send a SMS to a specified GSM number whenever the removal of fish plate is detected. Since the cost of sending a SMS in India is around 10p, this technology will make the system very effective without adding much cost. Fig 7 shows a basic structure of a GSM network.

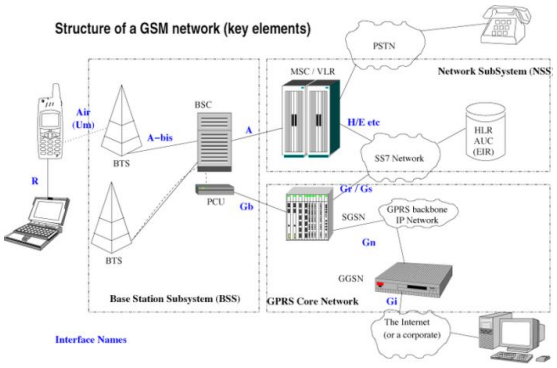

Fig. 7 Basic structure of a GSM network

3. Power System

The whole system will be powered by the solar energy which is plenty, free of cost and clean energy resource. Medium sized solar panel can be placed on the signal posts or small sized panels can be placed with IR sensors near the fish plate to power the tags, sensors and routers. A 5V/12V battery is connected parallely with the panel. The battery gets charged during the day time while the system is powered. During night or cloudy climate, the system is powered by batteries.

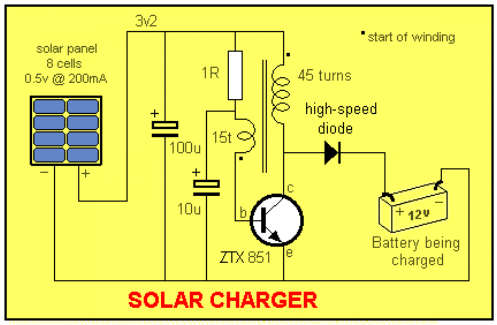

Fig 6– A simple solar battery charger circuit

Field Implementation

The proposed system was implemented on NTPC rail lines and was tested positive. The IR sensors were placed in the proposed places. The sensing system was integrated with RFID tags and routers and tracking software at remote station. The whole system was then put to testing. The results received were encouraging. Whenever, the fish plate was removed from the rails, an immediate response and warning message was received at tracking software. Following screenshots display the IR sensor implementation at the rails, and the warning message being received through the tracking software at the base station.

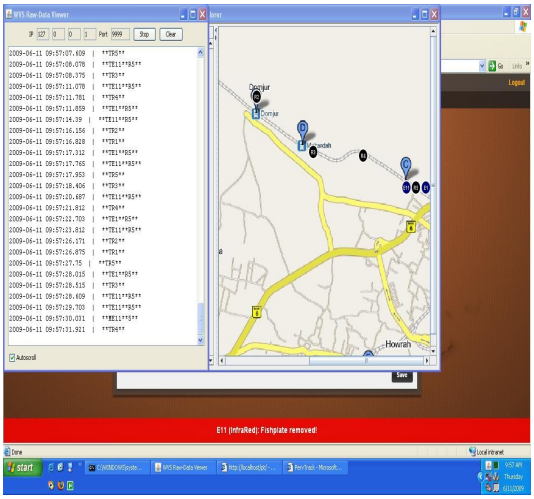

Fig. 8- Screen shot of tracking software showing warning message (in red) on removal of fish plate. Coursey: Pervcom Consulting Pvt. Ltd.

Future Work

The fish plate security using IR sensors and active RFID is an effective method. Easy availability of IR sensors, their low cost, readily available and easy to make IR modules make the sensing system very cheap and readily deployable. A lot of research and development has already been done in the field of active RFID which again help in making the system easy to produce. RF tags and routers are easily available and are of low cost. The IEEE 802.15.4/Zigbee based wireless mesh networking is a well developed networking system. All these attributes make the proposed system readily installable.

However, the major problem lies in the powering the proposed system. In the given paper, we have proposed to use solar energy as the power source. In both the proposed installation positions i.e medium solar panel position at signal posts and small solar panels at fish plates, the cost of panels is high. Each small sized panel will cost around Rs 1000 making the overall costing of the system high. Medium sized panels would be cheaper but wiring cost will add to the total installation cost. However, researches are being done to reduce the costs and sizes of solar panels. Once the cost of solar panel is reduced, the above proposed system will become economically viable too. Also, other renewable energy resource can be used. Recently, research is being done in the field of harnessing energy from the vibrations produced in railroads when a train passes on it. Recently, researchers at MEC (Interuniversity Microelectronics Centre), a microelectronics research facility on the outskirts of Leuven, Belgium, have been successful in creating a new micro-device that can harvest energy from mechanical vibrations, by using micromachining technology. These devices, consisting of zinc oxide nanowires, produce powers up to 40 mW, which is well in the range of power levels required by wireless sensor applications. If these devices can be integrated with our proposed system, it can easily power the sensors, tags and routers. If, again, these devices are made cheaper, they can be used as the power source in our proposed system.

Conclusion

Real Time Sensing system (RTSS) can be effectively used for the rail security. Here we have used the technology for security of fish plate against its illegal removal. A sensing system combined with IEEE 802.15.4/Zigbee based wireless networking system has been tested effective. We chose IR sensors for detecting the fish plate removal due to good efficiency, easy availability and low cost. Solar powered battery is used for powering sensors, tags and routers. A latest technology involving producing electricity from rail vibration using zinc oxide nanowires can also be used to power the whole system.

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