Research Article

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Automated Railway Crossing System Using ZigBee/IEEE 802.15.4 Standard

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Abstract
This paper presents a development of an automatic railway crossing system using a wireless sensor network based on ZigBee/IEEE802.15.4 standard. The existing works on automatic railway crossing system apply some technologies such as Fiber Optic, Coaxial Cable, and General Packet Radio Services (GPRS). However, they require high cost in their operation and complex installation. ZigBee allows us to develop a system with low power, low price that is suitable for automatic railway crossing system. We develop a new system that consists of four main parts, i.e. railway detector, ZigBee Wireless Communication Device, railway crossing gate, and monitor system. We propose an optimal recovery path routing algorithm based on ZigBee protocol in API (Application Programming Interface) mode to ensure the reliable data transmission from the source node to the destination node. Each node has two paths connecting to the neighboring nodes, where the transmission probability to the closer neighboring nodes is higher than that to farther nodes. The data are sent by the sensor node to monitor system and are displayed as the status of network link, status of the train detection, status of the railway crossing gate, and status of the sensors node in real time. From the data displayed in the monitor, we can also detect if there are any malfunctions on the sensor nodes. So we can fix the problem immediately. Moreover, the hardware system consists of solar cell panel, charger control unit, and battery storage designed for self- energy management and low power consumption. These features are suitable for installation in real environment. As a prototype of an automatic railway crossing system, the developed system in this project is very useful for further development and application in railway crossing system management in Thailand.

Keywords: ZigBee/IEEE802.15.4, Protocol, API mode, Railway crossing system

1 Introduction

Road accidents are the most prevailing cause of death in Thailand and one reason leading to these deaths are the manual traffic monitoring/control system. Railway Signaling System (RSS) is no exception to it. The place where track and highway/road intersects each other at the same level is known as "level crossing" Absence of railway crossing system is major reason for accidents for railway-road accidents. Currently in Railway state of Thailand, railway crossing system is manual thus prone to errors in addition to the cost associated with the workers on the site.

Automated monitoring and control systems are in high demand have their application in various ways of life. This paper presents railway crossing signal

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equipment remote monitoring system is used for automatic monitoring of railway signal equipment running status, through the remote wireless transmission mode, the railway crossing signal equipment running status real-time monitoring, remote monitoring, remote record of dynamic data management, remote analysis of a set of monitoring system [1].

This study analyses the reliability of an in-vehicle warning system. The system is based on the positioning of trains using GPS, calculation of the states of level crossings on a server and in-vehicle equipment that retrieves information about the states of level crossings from the server [2].

The existing works on automatic railway crossing system apply some technologies such as Fiber Optic [3], Coaxial Cable [4], and General Packet Radio Services (GPRS) [5]. However, they require high cost in their operation and complex installation. This paper presents a development of an automatic railway crossing system using a wireless sensor network based on ZigBee/IEEE802.15.4 standard. ZigBee allows us to develop a system with low power, low price that is suitable for automatic railway crossing system.

2 System Overview

We develop a new system that consists of four main parts, i.e. railway detector, ZigBee Wireless Communication Device, railway crossing gate, and monitoring system. The detector is used to detect the arrival and departure of the train. Two Infrared sensors are used to perform this action. One sensor is attached to the source for the detection of the arrival of the train. Upon detecting the train, instructions for closing of the railway crossing gate will be passed. The detector attached to the destination will respond to the presence of the object. Sensor will transmit the signal and if the signal is not bounced back, it implies that no object is present. In case the train is approaching then the transmitted signal will be reflected back and received by the sensor. If there is no reflected signal, it is assumed that there is no train on the path and instructions to open the gate will be passed to the railway crossing gate. A relay is used to connect the source and destination. ZigBee Wireless Communication Device is used to send and receive the data from source, relays and destination node. Monitoring system is very crucial and it performs a number of tasks namely: working of detector sensors,

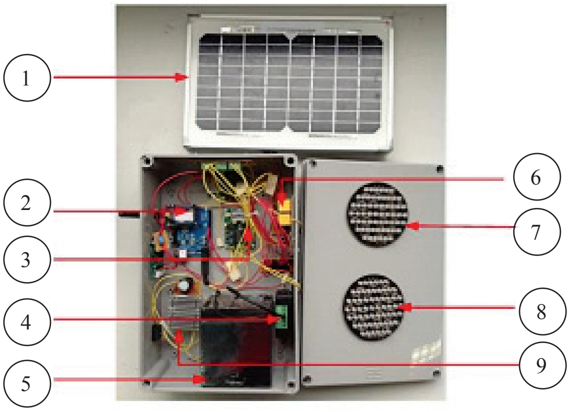

Figure 1: Control unit and power supply.

monitoring of communication link, railway crossing gate status, light control in every sensor module, information about the train and maintenance signals.

We propose an optimal recovery path routing algorithm based on [6] ZigBee protocol in API (Application Programming Interface) mode to ensure the reliable data transmission from the source node to the destination node. Each node has two paths connecting to the neighboring nodes, where the transmission probability to the closer neighboring nodes is higher than that to farther nodes. The data are sent by the sensor node to monitor system and are displayed as the status of network link, status of the train detection, status of the railway crossing gate, and status of the sensors node in real time. From the data displayed in the monitor, we can also detect if there are any malfunctions on the sensor nodes. So we can fix the problem immediately.

2.1 *Hardware design*

The hardware used in the nodes is shown in Figure 1 and details are explained as under. Solar cells are used for energy conservation and design is done is such a way to ensure easy installation in addition to energy efficiency

1. Solar panel having 5 Watt power and provides 12 Volts.

2. ZigBee Communication Module which works in ISM band at a frequency of 2.4 GHz. Data transfer rate is 250 kbps and consumes 50 mW power [6]. Arduino SMD microcontroller unit is used [7].

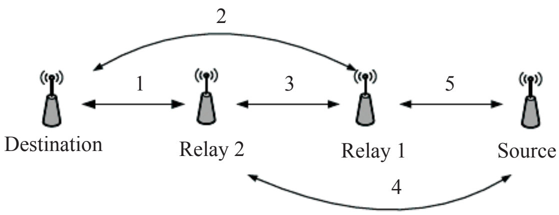

Figure 2: Optimal recovery path routing.

3. Two relays associated with green and red lights for opening and closing the gates [8].
4. Solar charge control unit for converting the solar energy to electrical energy.
5. 12 Volt and 5.5 Ampare battery to store the Charg.
6. Motor driver circuit [9].
7. Red Light LED panel.
8. Green Light LED panel.
9. Voltage regulator circuit.

2.2 *Software design*

2.2.1 Optimal recovery path routing

Keeping in view the severity of perfect functionality of railway crossing system, we proposed an optimal recovery path routing algorithm based on ZigBee protocol in API (Application Programming Interface) mode to ensure the reliable data transmission from the source node to the destination node. Each node has two paths connecting to the neighboring nodes, where the transmission probability to the closer neighboring nodes is higher than that to farther nodes. Relays in between the source and destination are placed in such a way that every node can transmit its information to next two nodes. In case the first node is not working, still message can be passed to the second node. This redundancy is used to bring reliability into the system. Figure 2 shows the above mentioned scenario.

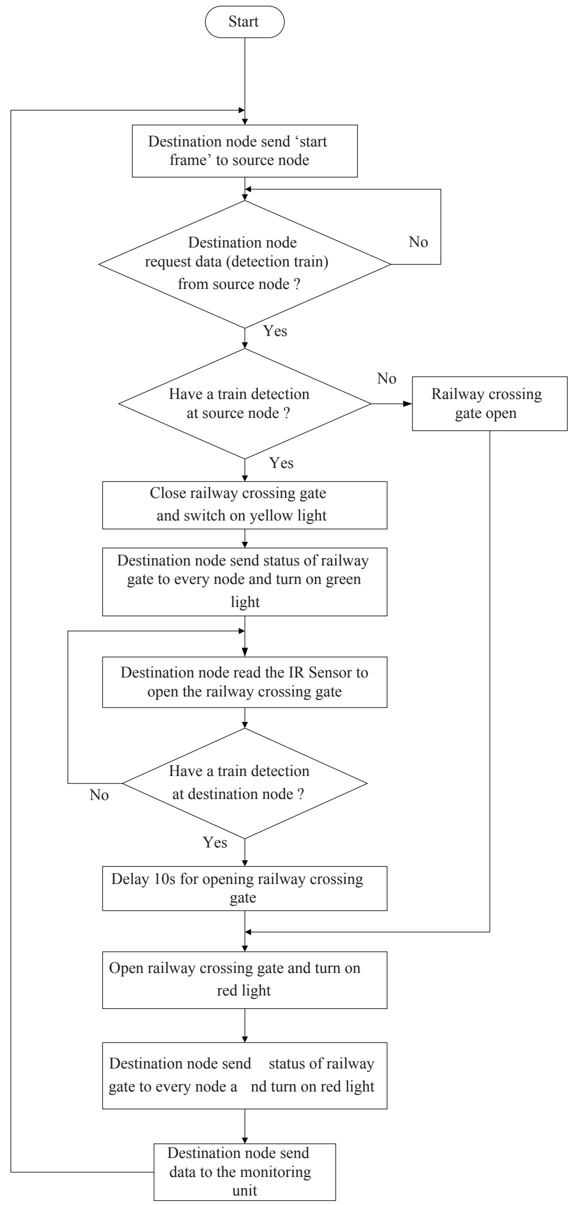

Figure 3: Flowchart of control system.

2.2.1 Flow Chart

Software design details are shown in Figure 3 Firstly, Destination node sent start frame to source node for beginning operations. Secondly, Destination node request data (detection train) from source node if have a train detection at source node the gate will close and switch on yellow light. After that destination node send status of railway gate to every node and turn on green light. Thirdly, Destination node read the IR Sensor to open the railway crossing gate if have a tain detection at destination node the gate will delay time 10 second and openning railway crossing gate and turn on red light. Finally, Destination node send status of railway gate to every node and turn on red light and then the destination node send data to the monitoring unit.

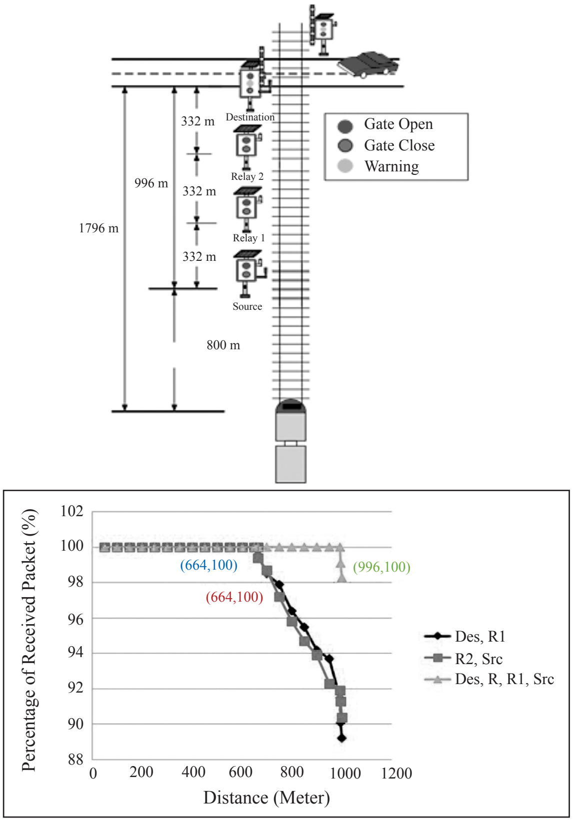

Figure 4: Packet loss rate in case of straight line of sight.

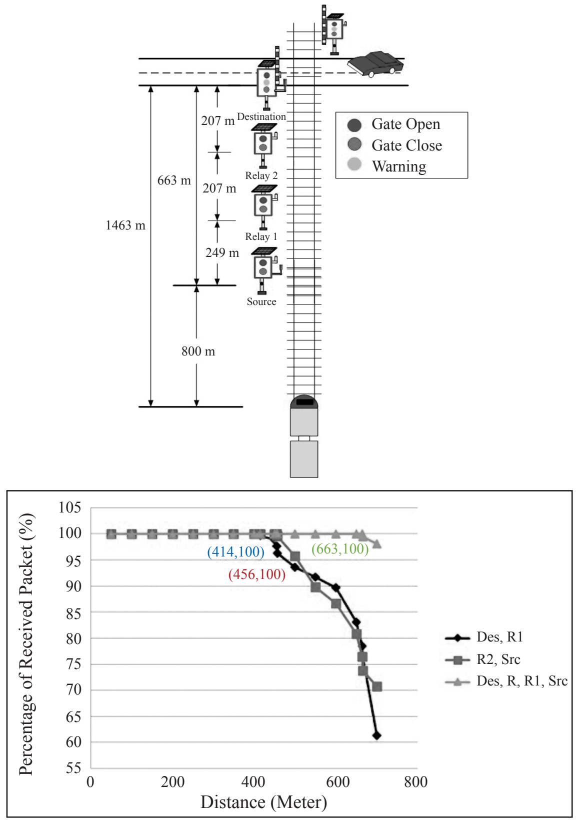

Figure 5: Packet loss rate in case of straight non-line of sight.

3 Testting Results

3.1 *Packet loss rate*

Keeping in view the diversity of railway lines, we tested our system for three cases.

1. Straight Line of Sight, Case 1 refers when a transmitting node can see the receiving node. This scenario is shown in Figure 4.

2. Straight Non-Line of Sight, Case 2 refers to when both the nodes are in the straight line but there is some object (for example tree) is blocking their way. This scenario is shown in Figure 5.

3. Curve. Case 3 refers to the area of the railway which is curve in shapes for helping the train to change its direction. This scenario is shown in Figure 6.

Our test results are summarized in Table 1. From the table we can see that our sensor nodes can work best if the nodes are line of sight as it can go to farther distance as compared to other cases.

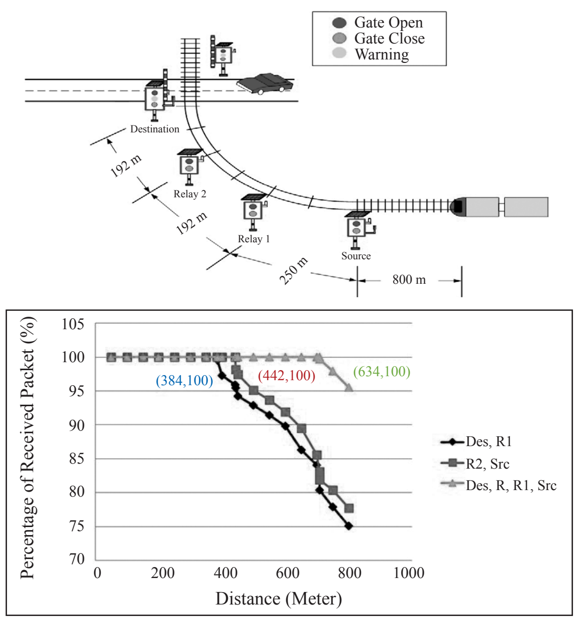

Figure 6: Packet loss rate in case of curve.

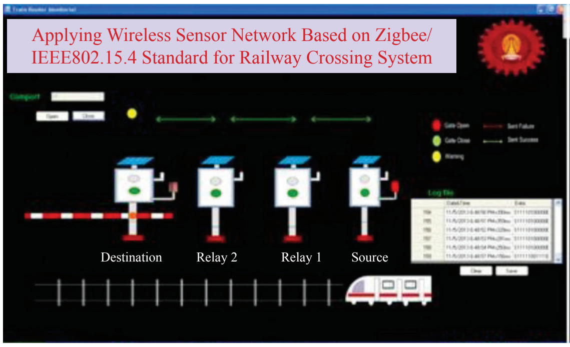

Figure 7: Monitoring.

Table 1: Test results for three cases

Case	Location	Distance (m)
Straight Line of Sight	Near Ramathibodi Hospital, Bangkok	664
Straight Non-Line of Sight	Near PhayaThai Station, Bangkok	414–500
Curve	Between Ramathibodi Hospital & PhayaThai Station	384–500

3.2 *End-to-End Delay*

We tested end-to-end delay for three scenarios 1) Straight Line of Sight 2) Straight Non-Line of Sight 3) Curve. Our test results are summarized in Table 2. It was observed that the case of curve test a high end-to-end delay more than scenario 1 and scenario 2.

Table 2: Test results for three cases

Case	End-to-End Delay (msec)
Straight Line of Sight	936.35
Straight Non-Line of Sight	936.43
Curve	937.28

3.3 *Monitoring*

The data are sent by the sensor node to monitor system and are displayed as the status of network link, status of the train detection, status of the railway crossing gate, and status of the sensors node in real time, as shown in Figure 7.

4 Conclusions

We presented a new technique for railway signaling system for developing countries. The hardware used in this system consists of solar cell panel, charger control unit, and battery storage designed for self-energy management and low power consumption. These features are suitable for installation in real environment. As a prototype of an automatic railway crossing system, the developed system is very useful for further development and application in railway crossing system management in Thailand.

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