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Review on Wireless Sensor Network Techniques for Security in Railways

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Abstract: Railways are considered as the safest means of transportation. But, lots of people suffer due to train accidents. According to a research, derail and collisions occur every ninety minutes. More than 10,000 train accidents had taken place in last eight years all over the world. Reasons for these accidents are human error, signal misinterpretation, system failures, improper maintenance of tracks and points. By controlling some of the parameters, many of such major accidents could have been prevented. In this paper, a survey on various technologies available in Wireless Sensor Networks (WSNs) is presented which could be used effectively to prevent such accidents so that enhanced security could be achieved in rail transportation.

Keywords: Wireless Sensor Network (WSN), Railways, MAC protocols, Routing Protocols.

Introduction

Accidents take place in railways mainly due to train collisions and derailment, fatalities due to people being struck by trains in motion either along the track or at crossings. Trains are one of the safe and secure ways to carry goods and passengers, but railway systems still need some improvements in order to assure total safety of passengers. Railway Ministry of India in [1] mentioned about the statistics of Train accidents. Table 1 lists the details of Train Accidents in India. In order to achieve safety, new technologies have to be incorporated with railways. Indian Railways lack in existing infrastructure. With the same available number of tracks, number of trains and their speed are increasing year by year. By using WSNs, a system can be established to monitor a rail line and harmful areas could be quickly identified so as to prevent a massive loss of lives. Using WSNs in railways leads to quick response and it is also cost effective. The most important feature of the WSNs is being multi-layered i.e. starts at the lowest layer and continues to the next higher layer.

WSNs for Railways

Figure 1 depicts a WSN used on a railway track. The network consists of one or more control centers (sink nodes/Base Stations) which are connected through a wire lined connection, and many wireless sensor nodes scattered across a railway track. Each of these sensor nodes is capable to collect the necessary data and forward the data back to the sink. This data is delivered to the monitoring system located at a remote site through networked connections between the different sink nodes [3].

Multi-homing is a widely used technique to improve the reliability of Internet by connecting to the Internet through multiple service providers [4]. Using broadcast communication characteristic of WSN, it is energy efficient to apply multi-homing technique for fault tolerance since no extra transmission energy is consumed to send multiple copies of the same data to multiple homes. With this technique, every node in the network is associated with two “homes”. The landmark nodes act as the “head of the home” (HoH). The members of each home are a group of sensors identified by their vicinity to the HoH. Each HoH works as a gateway that forwards traffic from one home to the other or to the main base station for processing. Multi homing adds the following features to the system:

- Better identification of the hazardous area, by narrowing it down to the overlapped region of the homes.
- Increases the robustness of the system so that it can function in the case of node failure, link failure, or misbehaving nodes.

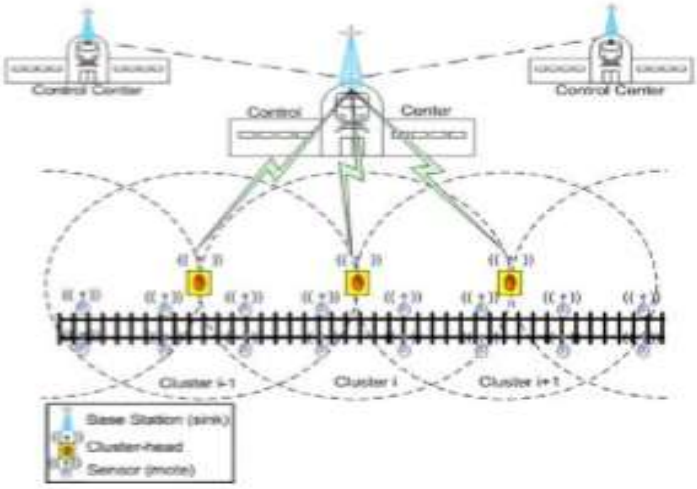

Figure 1: Railway system with wireless sensor nodes and control centers (base stations) [3]

Table 1: Survey of Train accidents in Indian Railways [1, 2]

Year	Collisions	Derailment	Accidents	Fire	Total
2004-05	13	138	70	10	234
2005-06	9	131	75	15	234
2006-07	8	96	79	4	195
2007-08	8	100	77	5	194
2008-09	13	85	69	3	177
2012-13	9	81	76	12	178

Literature Review

Zeinab Sam Daliri, et.al. in [5] have proposed a method for providing security in railways through WSNs based on Fuzzy Logic. It is based on the basic sensor network architecture and multi-layer routing and includes ultrasonic broken flaw detecting system. This system includes a transmitter which sends out high energy waves in two directions at estimated intervals. The break in rails will be indicated by the change in the amplitude of the waves. It has a system for tracking any materials in tracks which employs either image processing by analyzing the images captured by the cameras or leaky cable method for areas where there are possibility of landslides. Pascale,et.al. in [6] suggested the use of the wireless signaling for the computer based interlocking system in railways. In this architecture, they used a basic term Field devices that mentions about devices, sensor nodes which are fitted along the rail tracks and are located in the field network areas that consists of many individual field networks. Separate controllers for each network communicate using IEEE 802.15.4 to the Access point which further utilizes Wimax or GPRS connection to communicate with the control room. The authors concentrated on optimizing the number of deployed Access Points by reducing it with maximum reliability and minimal delay using Greedy approach and ILP formulation. Ayuub zinvand lorestani et al in [7] proposed a failure tolerant (FT) algorithm to provide monitoring of rail lines. In this algorithm, the network is divided into two parts, fixed and movable parts that has the ability to transfer information online or offline. At present authors of this article are designing and manufacturing platform for the practical implementation of this algorithm and they are testing it on rail line to evaluate the performance of these algorithms in a real environment. Also to increase efficiency in future, this algorithm can be implemented and be applied in the form of fuzzy logic.

Wireless MAC protocols for Railway monitoring Applications

Harnessing the potential benefits of WSNs requires a high-level of self-organization and coordination among the sensors to perform the tasks required to support the underlying application. At the heart of this collaborative effort to achieve communications is the need for the wireless sensor nodes to self-organize into a multihop wireless network. Consequently, the design of efficient communications and network protocols for WSNs becomes crucial for wireless sensor nodes to carry out successfully the mission for which they are deployed. The establishment of a multihop wireless network infrastructure for data transfer requires the establishment of communication links between neighboring sensor nodes. Unlike communication over a guided medium in wired networks, however, communication in wireless networks is achieved in the form of electromagnetic signal transmission through the air. This common transmission medium must therefore be shared by all sensor network nodes in a fair manner. To achieve this goal, a medium access control protocol must be utilized. The choice of the medium access control protocol is the major determining factor in WSN performance. A number of access control protocols have been proposed for WSNs [8].

A. TDMA

It is a schedule based MAC protocol; node has to be ON even if it has no data to send during its allocated slot. So energy consumption is high.

B. EA-TDMA (energy-efficient adaptive TDMA)

This protocol is used for providing communication between sensor nodes and the cluster-head (CH) placed in a railway wagon. It is appropriate for medium traffic conditions and provides reduction in energy consumption by reducing the idle period when device has no data to transmit.

C. BMA (Bit Map Assisted Protocol)

Jing Li et.al in [9] had proposed this Protocol which is based on communication among clusters and reduces energy wastage due to collision and idle listening. It works on the principle of Event driven networks in which transfer of data from sensor node to Cluster Heads (CH) takes place only on occurrence of an event. In BMA, the allocation takes place in the contention phase before the start of each frame so it is more energy efficient than TDMA and E-TDMA for low traffic. It has two phases**:** **Cluster Setup phase** - Cluster head is elected based on the energy levels of the nodes and other non cluster nodes join the cluster group. **Steady-State Phase** - It is assumed that the data slots have same size. This phase have many sections, each consisting of contention period, data propagation period and idle period. Contention period is used by the nodes for transmitting its data and indicates it by transmitting one-bit control message in its allocated slot or else remains silent. The cluster head gets the details of which nodes wish to transmit and a transmission schedule is sent for the source nodes by broadcasting. In the data Propagation period, the source node sends its data and then goes to off state.

D. E-BMA (Energy efficient Bit Map Assisted Protocol)

G. M. Shafiullah et.al in [8] explained about various energy efficient MAC Protocols specific for Railway Monitoring Applications with their limitations and proposed a new protocol called E-BMA which uses piggy packing technique to make reservations of the corresponding slot rather than sending an entire control message. It uses one bit field in header to indicate if any successive data packets are available which then helps the source node to wait for one more frame to check for the availability of the concurrent data packets. So this E-BMA protocol differs from the BMA in which reservation is made in the contention slot on the availability of a data packet. It has three phases for each round. **Setup Phase**: Cluster head formation, Cluster head selection. **Contention Phase**: reservation of data slots by the non- cluster head nodes. **Data transmission Phase**: nodes send their data to the Cluster Head. Data Aggregation takes place in Cluster Head and then sends it to the Base station using a spreading methodology and a Carrier Sense Multiple Access (CSMA) technique. The E-BMA protocol is better in terms of the energy efficiency for the low to medium traffic under simulation modeling of a Wireless Sensor Network scenario. Further energy efficiency could be achieved in this protocol by further modifications suitable for an application scenario.

Routing Protocols for Railways

Various Routing protocols suitable for railways [10] are:

E. Flat routing

It works like multihop adhoc routing protocol where each sensor node forwards the data through a parent node, but not as hierarchical clusters. It is assumed that all the location details of the sensor nodes and base station are known, thus, all nodes can reach the base station wherever they are located.

F. Tiny OS Beaconing

Beacon messages are broadcasted to the network by the base station. The nodes closer to the base station receives this message and assume it as its Parent node and further broadcast the message to its nearest nodes and so on. Later sensor data is periodically sent by the sensor nodes to its parent nodes which are further forwarded to their parents to reach the base station.

G. Pulse routing algorithm

This algorithm uses a Pulse source sending Periodic Pulse signal and this pulse is flooded to construct routing paths. Communication needs a reservation packet to be sent by the source.

H. Multilayer Routing

Sensor nodes are placed in and around the tracks forming different layers as shown in fig.2. Sensor nodes which are fitted to the tracks at regular intervals form layer 2 and at a fixed distance another layer(Layer 1) is formed .Each node in Layer 2 sends its sensed information to layer 1. Layer 1 sends this obtained information to the corresponding Cluster head which aggregates the sensor values from two of its layer 1 nodes and sends this to the base station which further takes appropriate action or sends it to sink nodes.

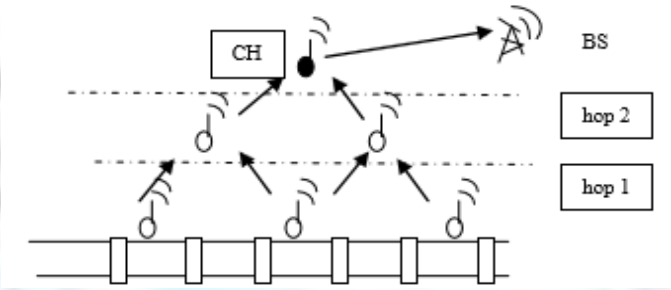

Figure 2. Multi-layered routing tree [2]

Conclusion

This paper presents a review on various Wireless Sensor technologies for providing security in railways and its routing and MAC protocols suitable for this application. In this paper we presented the model of our safe railway system with its different components including the wireless sensor nodes along with the control centers. Several techniques from each paper could be integrated to be used along with the existing railways infrastructure since entire replacement of existing techniques in railways is not possible.

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