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Full Length Article

Investigation on energy efficient sensor node placement in railway systems

Ayona Philipose, Rajesh A *

School of Electronics Engineering, VIT University, Vellore, Tamil Nadu, India

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ABSTRACT

Recently wireless sensor network (WSN) has been widely used for monitoring railway tracks and rail tunnels. The key requirement in the design of such WSN is to minimize the energy consumption so as to maximize the network lifetime. This paper includes the performance of an improved medium access control (MAC) protocol, namely, time adaptive-bit map assisted (TA-BMA) protocol, for the purpose of communication between the sensors placed in a railway wagon. The train is considered to be moving at a constant speed, and the sensor nodes are stationary with respect to the motion of train. The effect of mobility on the proposed MAC protocol is determined using genetic algorithm (GA), and the observed increase in energy consumption on considering mobility is 18.51%. Performance analysis of the system model is carried out using QualNet (ver. 7.1), and the energy consumption in transmit mode, receive mode, percentage of time in sleep mode, end-to-end delay and throughput are investigated.

1. Introduction

Wireless sensor network (WSN) consists of a large number of distributed sensor nodes which can be used to sense data from the physical environment [1,2]. These types of networks have many practical applications, and in this paper their applications in railway monitoring systems are discussed. WSNs are used to monitor railway tracks, rail tunnels, detect abandoned bodies in railway platforms, develop intrusion detection systems and secure railway operations. Due to the lack of safety and security monitoring, the railway runs the risk of train collision, derailment and possible terrorist threats [3]. Sensor network applications require long lifetime, data accuracy, and energy efficiency. Hence, power management is an important design constraint for WSNs. This is because sensor nodes are equipped with battery of short life, and they should use it efficiently in cases where the system operates for long durations [3,4].

Sensor nodes consume energy while sensing, processing and communicating sensed data. Each node can transmit only a fixed number of bits and in case a node has a heavy burden of communication, it gets depleted fast, thus affecting the entire network [5]. In WSN, major waste of energy happens due to collision, idle listening, overhearing, presence of overhead, etc. Various energy saving methods are proposed for medium access control (MAC) protocols in WSN to avoid wasting the limited energy [3,6]. Energy efficient MAC is necessary for the successful operation of shared medium networks. The MAC can be of contention based or schedule based protocol. Among these protocols, schedule based protocols are collision free and thus save energy wasted due to collision.

In Reference 6, scheduled-based Time-division multiple access protocol (TDMA) has been discussed, in which the transmission channel is divided into several time slots and each node is assigned a time slot. Each node wakes up and transmits data only in its allocated time slots and remains in sleep mode at other times. This protocol is energy efficient only when the traffic load is high. In Reference 3, an energy efficient adaptive TDMA (EA-TDMA) protocol has been proposed, where every node wakes up in its allocated time slot and checks transmit buffers. If there are no data to transmit, it turns off the radio immediately. This protocol reduces energy consumption by idle listening.

In Reference 1, a bit map assisted (BMA) protocol intended for event-driven applications have been proposed, where sensor nodes transmit data to cluster head only if significant events are observed. Here time slot is allocated in the contention phase before starting of each frame unlike in TDMA and EA-TDMA where a data slot allocated to a node persists for all frames in that round. In Reference 7, an energy efficient bit map assisted protocol (E-BMA) has been proposed, in which the source nodes use piggybacking to make reservation of the corresponding data slot. Unlike BMA, it does not make reservation in the contention slot as soon as the data packet is available, but it waits for one additional frame duration to see if there is a successive data packet to send. This protocol is energy efficient at low and medium traffic.

* Corresponding author. Tel.: +91 9994220967, fax: +91 4132655368.
E-mail address: rajeshtechece@gmail.com (R. A).
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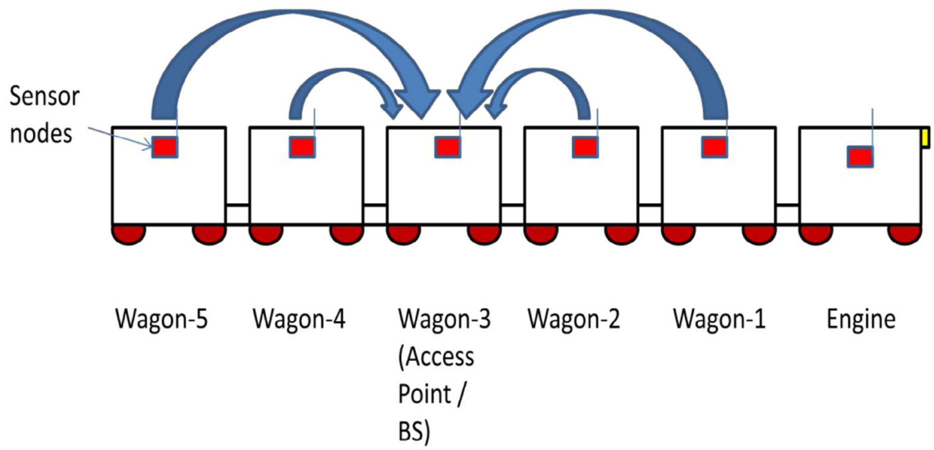

Fig. 1. Prototype of the system model.

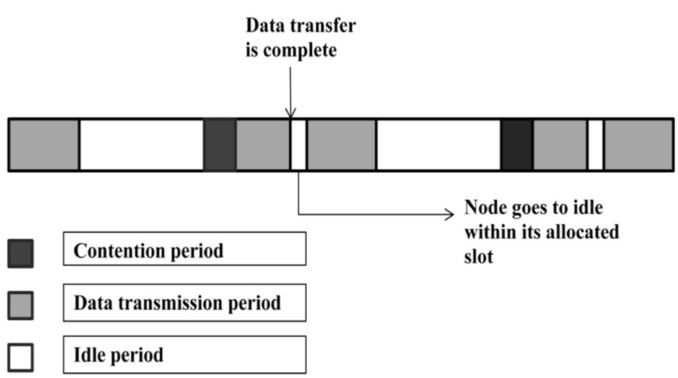

Fig. 2. Timing operation of TA-BMA.

In this paper, a time adaptive bit map assisted protocol (TA-BMA) has been proposed considering node placement in wagon. This protocol uses clustering techniques to monitor vertical acceleration and lateral instability of railway wagons. In this protocol, each node wakes up in its allocated time slot but goes to idle immediately after data transfer is over. A mathematical model has been developed to evaluate the performance of this cluster-based TA-BMA protocol. This paper also focuses on the various deployment scenarios of sensor nodes inside train wagons, namely, four sensor nodes placed at four corners of wagon, eight nodes at four corners, eight nodes at four corners of which four nodes are active first and remaining nodes become active when the first four nodes die, and four nodes at four corners in which corner node with maximum energy becomes cluster head as prevailing cluster head dies.

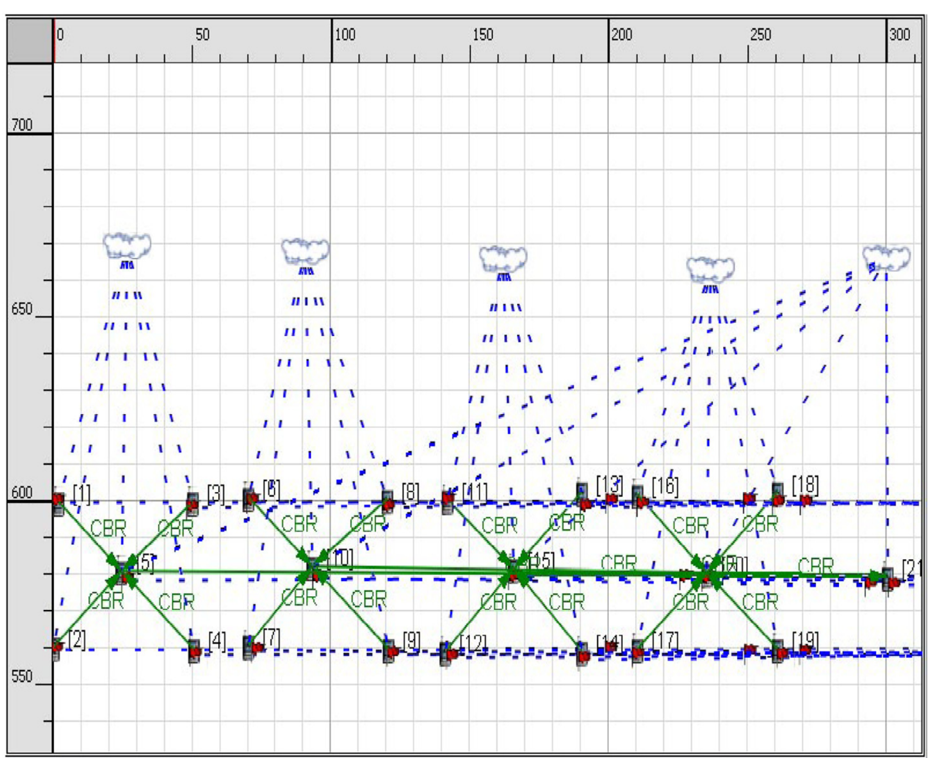

Fig. 3. 2D view of system model in QualNet.