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SMART ID-TAGS for LOCATING FREIGHT WAGONS and OPTIMIZING MAINTENANCE PROCESSES

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Summary:

This work presents a prototype of a wireless ID tag that is to be used in the field of rail vehicle maintenance. The ID tag helps to localize vehicles, stores condition and environmental data and provides an interface to existing maintenance systems. Energy-saving, simple low-cost components are used in the circuit board design. The prototype can be further optimized in terms of size, energy efficiency and functions.

Keywords: ID Tag, wireless, efficiency, mobility, maintenance

Introduction

The railway system serves as a backbone of transportation infrastructure, facilitating global commerce and connectivity. However, ensuring the digitalization, reliability and safety of railway operations necessitates a proactive approach to maintenance [1]. Smart maintenance uses innovative sensor technologies tailored to the unique demands of railway, particularly in the context of environmental and biophysical data monitoring. To work with wireless components in dynamic systems is key here.

A smart ID tag serves as the foundation for digital wagon records in rail transport by integrating advanced sensor technologies into the railway-operating infrastructure. Special emphasis is placed on wireless communication protocols to facilitate effective monitoring of condition, environmental and positioning data. While sensors employed in various industries for condition monitoring and predictive maintenance, their adaptation to the railway environment presents unique challenges and opportunities. The dynamic nature of railway operations, coupled with the harsh environmental conditions, the need of energy saving solutions and stringent safety requirements, necessitates specialized sensors. The sensor system comprises a suite of advanced sensors capable of capturing environmental parameters such as temperature, humidity, vibration. Through the integration of wireless communication, a sensor network can enable real-time data collection, processing, and analysis, empowering railway operators with actionable insights for proactive maintenance decision-making.

Prototype Design Concept

The whole system works with a supply voltage of 3.3 V, which makes it perfect for battery applications, which can be additionally supported by energy harvesting technologies. An 8-bit Microcontroller collects data from two analog sensors IC's (integrated circuit). On the one hand, we detect vibrations that are transmitted to the sensor via structure-borne sound. The vibration data can be used to detect defects in machine parts or even flat spots on the wheelset of a freight wagon. The flat spots on a wheel produce a periodic impact that can be detected by measuring acceleration, as illustrated in Fig. 1, and applying a periodic peak detection algorithm to the signal.

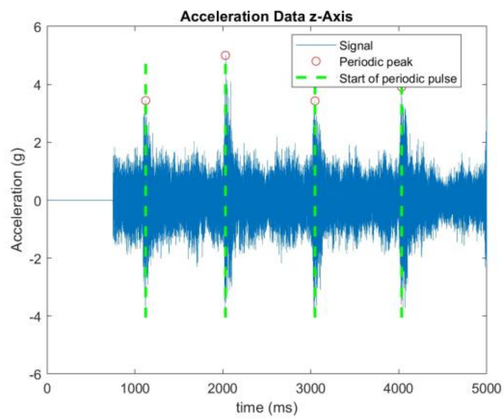

Fig.1 Detection of periodic signal

On the other hand, we measure temperature and humidity as examples of environmental data. These variables provide information about the condition of the environment surrounding the sensor node. This data can later be used for correlations between defects and environmental influences in order to predict failures earlier. All data is transmitted to a radio module via UART. The module uses a Zigbee Network and operates in AT mode (Application Transparent), in which all data is simply forwarded to the target address. The localization of the vehicles operates by combining multiple technologies. The reason for this is to increase the robustness of the localization to counteract impairments such as the shielding of satellite signals in tunnels.[2] The ID tags communicate with each other via a mesh network and, in relation to a train, determine their position using Downlink TDoA (Time Difference of Arrival) [2]. Another way of calculation the position of the nodes is measuring and evaluating RSSI values of the received signals [3]. Fig. 2 illustrates a mesh network applied to the field of freight train localization. The green dots symbolize nodes for data collection. The blue ones are nodes for data forwarding or stationary nodes like balises in the infrastructure [4].

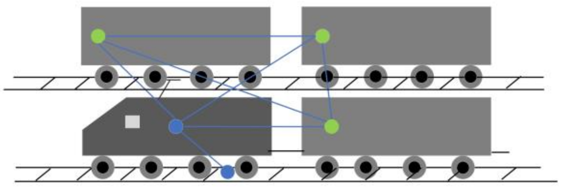

Fig. 2 Mesh Network for TDoA Localisation

Both the microcontroller and the radio module can be put into sleep mode to save energy. The module is in pin sleep mode, controlled by the microcontroller. However, this only happens in the event of successful network access. If a wagon does not move for a longer period, the entire system should be in sleep mode to avoid wasting energy. To detect the movement of the train and wake up the microcontroller, we use the 3-axis acceleration sensor on the circuit board, to be more precise the Analog Digital Converters interrupt enable function.

Fig. 3 shows a current prototype with external dimensions of 50 mm x 60 mm, which can easily be reduced to at least half the required space, if the small-factor packages of the components are used and the rear side of the PCB is fully utilized.

Fig. 3 PCB design of the Tag prototype.

Discussion and Conclusions

The presented smart ID tag demonstrates one way to integrate wireless technologies into railway systems. By including multiple sensors in the system, it can collect condition and environmental data with minimal invasive installation and legal authorization requirements. The greatest challenge lies in the interaction of different communication technologies in an energy saving way. Further research with Zigbee must test whether interference with other high-frequency signals, such as WLAN, occurs, as Olaby et al. 2022 measured in the context of RFID technology [5]. The programming of associated software and software interfaces to existing data processing programs. However, the data collected brings great benefit for training intelligent algorithms for predictive maintenance. The design tries to find the sweet spot between energy efficiency and functionality.

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