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Providing Wireless Bandwidth for High-speed Rail Operations

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Abstract

American railroads are in the process of introducing a wireless network-based control system – commonly referred to as positive train control (PTC) – to share the railroad among multiple trains, worker vehicles, and other support entities. A major challenge with adopting a wireless based communication systems for high-speed rail (HSR) is the limited bandwidth availability in the USA. The objective of this paper is to analyze the sufficiency of the 220MHz frequency range in supporting PTC-like operations for high-speed trains.

The paper begins with a frequency analysis that shows the advantages of using different modulation schemes and channel bandwidths to gain data rates and supporting signaling and beacon networks that uses PTC packets formats. PTC places limitations on the wireless trains speeds with the number of packets required to establish a connection and a minimum distance between overlapping cells, using proposed packet formats. Additionally, using a guard band that can eliminate the Doppler effect caused by increasing train speeds. For example, using a guard band of 300Hz can eliminate the Doppler shift at speeds less than 400mph.

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Keywords: Positive Train control; Frequency planning; high-speed trains

1. Introduction

High-speed rail operations will bring significant societal benefits to the regions they serve and to the traveling public in general in the U.S.A. European and Asian high-speed trains use GSM-R, a special-purpose extension of the GSM protocol used for cellular telecommunications. GSM-R supports a unified Communications-Based Train Control (CBTC) system known as the European Rail Traffic Management System (ERTMS). ERTMS supports high-speed rail services in Europe and is being adopted in India and China (1).

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There is a move to introduce high-speed rail services in the West Coast of the USA, similar to the North-Eastern corridor, between Boston and Washington D.C. Class-one freight railroad companies (BNSF, NS, CSX and UP) and the main high-speed passenger railway company, Amtrak are collaborating on providing an interoperable Communication Based Train Control (CBTC) system, using their E-VTMS (Enhanced Vessel Traffic Management System) (2), originally designed by BNSF. American railroads use the 220MHz frequency range [217-219MHz for the uplink and 221-222MHz for the downlink] for rail signalling.

We answer the main question of computing the maximum attainable speed using the 220MHz frequency band for ERTMS-like signaling mechanisms for American high-speed trains. The rest of the paper is organized as follows. Section 2 describes the PTC architecture and PTC message formats, as our computations are based on this model. Section 3 discusses the frequency analysis that was carried out to see how the available frequency band should be divided to support train operations. Section 4 discusses related work and Section 5 provides conclusions.

2. PTC System

2.1. PTC Architecture

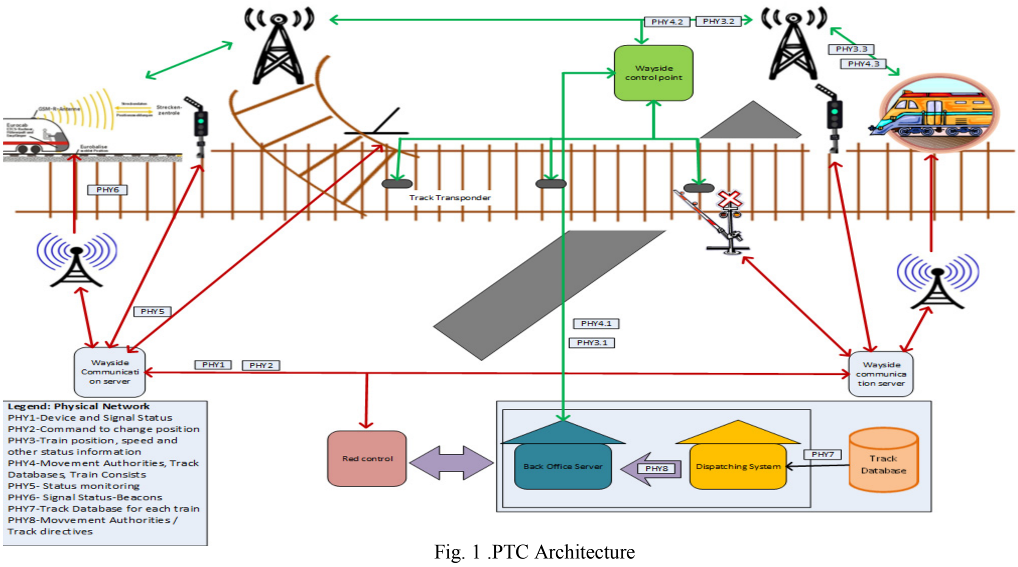

Fig. 1 .PTC Architecture

Fig.1 shows the main components of the proposed PTC system. As shown at the top half of the diagram, on-track train movements are governed using authorities communicated through a system of networks connecting the back offices that are in charge of managing the track segment. The logical connectivity of this part is shown as the “green network”. With the exception that Amtrak’s uses ACSES2, a track-mounted transponders to convey movement authorities using a four-aspect signal encoding, it is ideal for an integrated system to only use wireless communications. In addition to this envisioned PTC system, existing externally mounted and in-cab signals provide movement authority and track condition notifications, including but not limited to switch positions using wayside devices. This existing signal network is shown at the bottom of Fig. 1 as the “red network”. Where in-cab signalling is available, the red network may use wireless communications, track mounted sensors (as in Amtrak’s Northeast corridor) or provide wired external signals. In either case, movements can be controlled using signals and existing voice-based radio communication. In the ideal situation, with the full implementation of PTC as a vital system, the red network should be merged with the green network using the same wireless protocols. We use this logical view as a basis to analyse bandwidth requirements for high-speed traffic. Given existing agreement between the railroads to use EVTMS we use EVTMS as the PTC system that will be used in high-speed rail operations in the U.S.A.