Adaptive MIMO algorithms for train-to-wayside transmissions in tunnels

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Abstract— **This paper presents possible enhancements of the PHY layer wireless systems deployed in tunnels based on MIMO techniques with and without channel state information at transmitter in order to increase system performance without increasing the number of deployed access points and the transmitted power. We consider spatial multiplexing, space-time block codes, max-d_{min} and P-OSM precoders at 5.8 GHz with a targeted Frame Error Rate equals to 3.10^{-2} for a frame length of 100 bytes. The MIMO algorithms are compared in terms of achieved signal to noise ratio (SNR) versus spectral efficiency.**

I. Introduction

Driverless metro systems rely on train-to-wayside wireless communication systems based on IEEE 802.11a/b/g modems deployed along the tracks and offering robustness, high data rate and QoS (Quality of Service) for vital and non vital applications. We will show how precoders can provide efficient solutions to improve existing WLAN systems using MIMO techniques without increasing the number of deployed access points and the transmitted power with the same final targeted performance in term of maximum tolerable frame error rate.

II. System description and targeted KPI

The simulation chain developed mimics the IEEE 802.11x PHY layer and we have added MIMO algorithms with or without partial CSI-T.

First, conventional MIMO algorithms without knowledge of CSI-T are investigated. We consider spatial multiplexing (SM) and full rate space time block codes (STBC) and we focus on turbo equalization. Second, We have implemented two specific precoders: max-d_{min} [1] and precoded orthogonalized spatial multiplexing (P-OSM) [2,3] with full and quantified CSI-T.

The targeted performance indicator discuss with industry for the application is a fixed frame error rate (FER) equals to 3.10^{-2} for a frame length of 100 bytes. With this FER, the objective is to compare the MIMO algorithms in terms of achieved signal to noise ratio (SNR) versus spectral efficiency.

III. Tunnel scenario and channel model

We consider a tunnel scenario with a parked masking train between the transmitter and the receiver. We focus on two antenna configurations at 5.8 GHz: a high correlated one (EP_1RP_1, with a mean correlation level equal to 0.97) and a low correlated one (EP_2RP_2, with a mean correlation level equal to 0.53). The MIMO channel matrices are obtained using a 3D ray-tracing based tool [4] and then we compute the Kronecker model [5]. The channel matrices are in narrow band, due to the small RMS delay spread in such an environment regarding the data frame size.

IV. Performance analysis with and without CSI-T

For an uncorrelated scenario, whatever the chosen MIMO scheme without CSI-T, performance is largely improved by 15 dB compared to the SISO case. In uncorrelated and correlated scenarios, max-d_{min} outperforms P-OSM. However, from a practical point of view, P-OSM is a good alternative to MIMO schemes without CSI-T, even in correlated scenarios, since only a 7 bits feedback is needed and SVD is avoided.

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