Spectrum Survey in 2.4 GHz ISM Band for a MRT Station Located in Singapore

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Abstract—**Recently, a spectrum survey was performed at a Mass Rapid Transit (MRT) station located in Singapore for the study of spectrum utilization in the 2.4 GHz ISM frequency band. The measurement results indicate that the 2.4 GHz ISM band is highly crowded by the WLAN signals and the CCTV signals in this MRT environment. The presence of WLAN signals and CCTV signals increases the potential of interference to the Communications-Based Train Control (CBTC) signals and therefore creates the risk of frequent failures in train control.**

An occupancy analysis is then carried out to study the severity of interference from those Non-CBTC signals to the CBTC signals. The results present that maximum occupancy in the 2.4 GHz ISM band could be up to 58.76 %, which is significant enough to introduce spectral congestion for the CBTC system.

I. INTRODUCTION

Spectrum survey is essential to investigate the frequency usage pattern of different services in different frequency bands. This will help in finding the source of interference signals which can degrade the performance of the communication systems. About a decade ago, a spectrum survey was performed in Singapore [1], which concluded that the 2.4 GHz ISM frequency band is the least utilized band. However, with the rapid increase in the usage of WiFi and Non-WiFi devices in recent years, the 2.4 GHz ISM band is now heavily utilized.

Communications-Based Train Control (CBTC) is a modern railway technology adopted to improve the safety and operational performance of the Mass Rapid Transit (MRT) systems [2]. The CBTC system uses IEEE 802.11 standard WiFi system with Frequency-Hopping-Spread-Spectrum (FHSS) technique for communication. The performance of the CBTC system completely relies on a reliable wireless communication system along the train track [3].

Due to the frequency band of operation the CBTC system is susceptible to interference from WLAN (IEEE 802.11b) and Non-WiFi devices within the ISM band. The interference typically becomes severe especially in densely populated areas such as Singapore. The possibility of interference to the CBTC signals is high at the MRT station environment, due to existing strong Non-CBTC signals operating within the ISM band (WLAN, CCTV, Bluetooth, etc.).

In this paper, we will report a recent spectrum survey at a MRT station located in Singapore, to better understand the spectrum utilization for proper CBTC radio planning. In the remaining of this paper, details of the experimental setup and methodology will be described in Section II. In Section III, measurement results and analysis for this spectrum survey will be presented. Finally, concluding remarks will be drawn in Section IV.

II. EXPERIMENTAL SETUP & METHODOLOGY

The spectrum survey was performed at the Boonlay MRT station in Singapore. This MRT station is surrounded by a shopping mall with a free WiFi service. The measurement setup was placed in the front car of the train carriage. An omni-directional antenna was used for environmental surveillance and placed near the glass window area. The received signal was captured by a spectrum monitoring equipment.

The 2.4 GHz ISM band spectrum was captured by dividing the entire band into 3341 sweep points. The step size was fixed at 25 kHz. The noise floor of the spectrum monitoring equipment was noticed to be around -120 dBm. Totally 688 spectrum traces were recorded for analysis.

III. RESULTS & DISCUSSION

The radio signals monitored in the 2.4 GHz ISM band at the MRT station can be classified into CBTC signals and Non-CBTC signals. The CBTC signals are the radio signals which communicate the safety information among trains and wayside infrastructure, while the Non-CBTC signals are from other sources such as IEEE 802.11b WLAN, CCTV signals, and Bluetooth signals from computers, electronic gadgets, Zigbee devices, and cordless phone.

A. Bandwidth and Strength of Signal

The required bandwidth for CBTC signals and Non-CBTC signals are illustrated in Fig. 1. Among Non-CBTC signals, the CCTV signals are consistently available at all the MRT stations and are used to transfer the video security information from the monitoring cameras to the trains. The occupied bandwidth of these signals depends on the required video-resolution, which is typically greater than 3 MHz. The IEEE 802.11b standard allocates 2.4 GHz ISM band into 13 channels with a bandwidth of 22 MHz each, where 3 of 13 channels are non-overlapping. It is noted that Channel 1 (2.401 GHz - 2.423 GHz), Channel 6 (2.426 GHz - 2.448 GHz) and Channel 11 (2.451 GHz - 2.473 GHz) are the channels most widely used.

The CBTC system uses an FHSS technique for signal transmission, and therefore CBTC signal hops at different frequencies every time. Fig. 2 presents a waterfall diagram of the 2.4 GHz ISM band spectrum survey in this study. The waterfall diagram consists of 688 traces recorded in 78 seconds

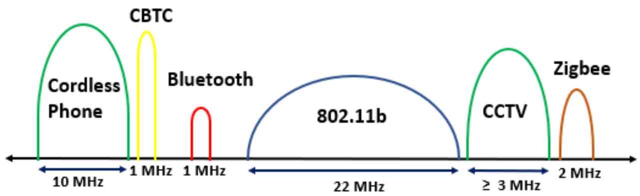

Fig. 1: Devices using 2.4 GHz ISM band in a MRT station.

duration in between 08:12:11 AM and 08:13:29 AM. From the results in Fig. 2, it is observed that a strong wideband CCTV signal exists around 2.45 GHz center frequency in this MRT station, and it is highly likely to cause severe interference to the CBTC signals of interest. A few CBTC signals are observed at a different frequency (by Frequency-Hopping technique) and are highlighted in yellow circles.

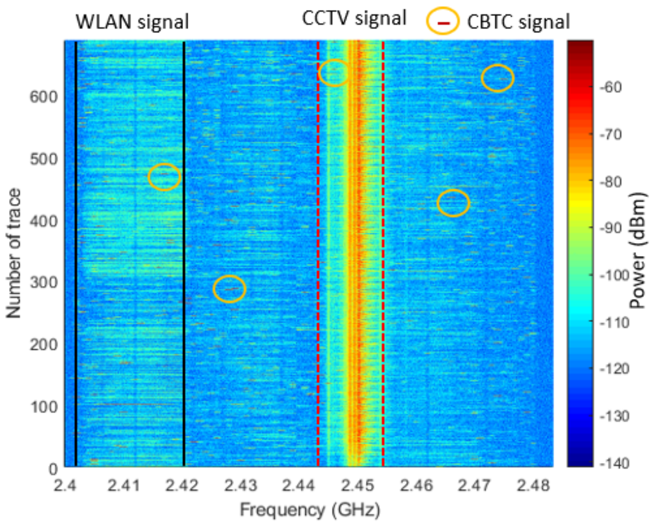

Fig. 2: Typical waterfall diagram for spectrum survey.

Moreover, it is also observed that the existence of stronger signals in Channel 1, which suggests more frequent WiFi access in this channel during the spectrum survey. The stronger Non-CBTC signals could bring up the noise floor which may cause unintended information loss of CBTC signals. The presence of these WLAN signals within the same frequency band could introduce potential interference to the FHSS CBTC signals. The severity of the interference effect will increase accordingly with the signal strength of Non-CBTC signals.

B. Spectrum Occupancy

Spectrum occupancy is a metric used to define the amount of spectrum detected above a certain received-power threshold. The occupancy of the ISM band is calculated over 688 traces recorded at the MRT station. The threshold to decide the presence of a signal is chosen to be -110 dBm which is 10 dB above the equipment noise floor.

The results show that the maximum spectrum occupancy is about 58.76 % over 83.5 MHz of 2.4 GHz ISM band, and the median spectrum occupancy is about 34.28 %. The CCTV signal is found to have a median spectrum occupancy of 8.67 MHz, and the CBTC signal occupies a bandwidth of about 1 MHz. Other than the CBTC signal and CCTV signal the existence of a WLAN signal can be noticed in Fig. 2. The presence of CCTV signals and WLAN signals can introduce the performance constraint to the CBTC system and result in a lower data rate.

In general, the 2.4 GHz ISM band is crowded by the WLAN signals especially in an MRT station. The usage of CCTV signals in the ISM band will bring in additional congestion. With the presence of strong WLAN signals and CCTV signals in the ISM band as observed in Fig. 2, it is very challenging to avoid the CBTC signal failure caused by interference. Moreover, the MRT stations surrounded by residential buildings and shopping malls such as the one presented here will suffer from highly likely interference and results in train signal failure.

The overall occupancy of the spectrum is calculated by considering the spectrum occupied by the CBTC signal, CCTV signal, WLAN signal, and Non-WiFi signal. In this study, the presence of a strong WLAN signal occupies the frequency band of 2.401 GHz to 2.423 GHz as noticed from Fig. 2. Although the WLAN signal is occupying Channel 1 in this measurement results, the WLAN signals could occupy a maximum of 66 MHz bandwidth with strong signal strength in Channel 1, Channel 6, and Channel 11. Severe interference cases can exist when Channel 1, Channel 6, and Channel 11 of WLAN and the CCTV signal almost fully occupy the 2.4 GHz ISM band. In this case, the available bandwidth for the CBTC system is very low.

IV. Conclusions

A spectrum survey was performed in the 2.4 GHz ISM band at one of the MRT stations located in Singapore. This study was performed to investigate the challenges in providing reliable wireless communication using the CBTC system and figure out the potential source of interference.

The measurement results indicate that the ISM band at the MRT station under investigation is highly crowded with the WLAN signals and the CCTV signals. The existence of these signals will increase the chances of interference to the CBTC signals.

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