Safety Improvement in Millimeter Wave Vehicle-to-Infrastructure Communications

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ABSTRACT

Message transition with the lowest possible delay, is a critical need for safety applications of vehicle communications. But how we can reduce such delays? In this paper, we investigate the use of millimeter waves (mm-waves) due to their wide bandwidth and higher data rates, compared to dedicated short range communication (DSRC) technology for vehicle-to-infrastructure (V2I) communications. We use a 3D ray tracing technique over two different actual environments: a high dense urban, and a low dense sub-urban area. Simulation results reveal that mm-waves have lower delay spread compared to the current DSRC technology.

Keywords: ***ray tracing*, *vehicular communication*, *vehicle-to-infrastructure*, *delay spread.***

1. INTRODUCTION

In recent years, vehicular transportation is facing several challenges such as increasing safety, traffic efficiency, and reducing congestion and road accidents [1]. Traffic accidents are the leading cause of 1.2 million deaths and 50 million injuries annually, on the world's roads [2]. The annual economic costs of road traffic accidents are shown to be about 518 billion USD in high income countries, and 65 billion USD in medium and low income countries [3]. These costs and damages can be reduced by using new communication technologies such as vehicle-to-vehicle (V2V) and vehicle-to-Infrastructure (V2I) communications, where the vehicles can share awareness data and the information of their sensors and radars. However, the average number of vehicle sensors is about 100 per vehicle, with an increasing trend. It is expected to reach 200 sensors per vehicle by 2020 [4].

These number of sensors and equipment will generate a huge amount of data. As an example, sensors on Google's self-driving car can produce up to 750 megabytes per second [5]. Some other studies show that automated driving cars might have a sensor data of 1 terabyte of data per single trip [6]. This high amount of data can help to exchange low-level sensing data (and maybe infotainment data applications) to ease traffic on roads, improve traffic safety (by providing 360-degree awareness, emergency break, awareness for entering the road at cross, and etc.) and traffic efficiency [5], [7], [8].

The current technology of vehicular communications, known as Dedicated Short Range Communications (DSRC), works at 5.9 GHz (with a bandwidth of 75 MHz in U.S.A) and it can only support a data rate of 6 Mbps to 27 Mbps [9].

Multi giga-bits-per-second (Gbps) vehicle communications can be realized by employing millimeter-wave (mm Wave) spectrum due to available wideband channels in these range of frequencies [10], [11]. Although higher data rates are desired in vehicular communications, delivery latency is the most important performance metric for road safety applications, in a way that emergency messages are expected to be delivered with no or very low latency [12].

In [9], [13], the use of mm-waves in vehicular communication to achieve several Gbps data rate, by employing array antennas with directional beam, and beam alignment technique (between transmit and receive antennas), is studied. Several studies have discussed safety applications over DSRC [8], [12], and ray tracing has been a useful technique to estimate delay spread. A 3D ray tracing (or a combination of 2D and 3D) can be applied for wideband communications [14].

In this paper, we use a 3D ray tracing model to investigate delay spread of millimeter waves at 60 GHz, compared to DSRC at 5.9 GHz for V2I communications in urban and suburban environments. The remainder of this paper is organized as follows. We introduce the propagation model in Section 2. Then, delay spread analysis is addressed in Section 3. It follows by comparing the effect of frequency and bandwidth on the delay spread in Section 4. Finally, Section 5 concludes the paper.