Next generation vehicular communications via interworking of DSRC and TV White Space

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***Abstract*—In this work, we propose the use of TV White Space (TVWS) to complement the operation of DSRC technology in vehicular environments, as a Next Generation Mobile Communications platform for vehicular networking. When a DSRC channel is highly congested due to an increased vehicular density or network traffic, a TVWS network could be used as an offloading option to meet the strict delay required for applications, in particular for emergency messages dissemination. We compare the behavior of a DSRC network and a TVWS network for the case of V2V communications, when emergency messages need to be disseminated in urban and suburban environments. We take into consideration realistic signal propagation models for each network, the distance between vehicles, and the minimum number of hops required when a multi-hop dissemination mechanism is used. We show that the delay using TVWS is less than the delay using DSRC in NLOS urban and suburban scenarios, making TVWS a good candidate for message dissemination when the main network cannot guarantee message delivery.**

I. Introduction

Although the DSRC coverage for vehicle-to-vehicle (V2V) communications is up 300 m, transmissions in the 5.9 GHz band suffer degradation due to the low penetration of obstacles. Therefore, priority messages must be sent using multi-hop dissemination mechanisms when long distances need to be reached. In the case of road safety applications, where the maximum delay for sending messages is 100 ms, a multi-hop dissemination mechanism adds extra delay that affects the performance of the application. This situation worsens in high density traffic scenarios, where a high number of vehicles sending messages produces channel degradation because of the collisions during channel contention.

To reduce the congestion in the Dedicated Short-Range Communication (DSRC) channels, and as a Next Generation Mobile Communications platform for vehicular environments, we propose the interworking with an opportunistic network such as TV White Space (TVWS), where available TV channels could be used for other applications different from Digital Television services [1]. One of the main advantages of the TVWS network is its large coverage due to the high obstacle penetration, and small losses over long distances in frequencies up to 1 GHz. This network could be used as an alternative access network to reduce congestion of DSRC channels in scenarios where emergency messages dissemination should cover long distances (i.e., more than 100 m).

To demonstrate the effectiveness of the TVWS network, in this work we compare the behavior of DSRC and TVWS technologies for emergency messages dissemination for V2V communications in urban and suburban environments. In the comparisons, we consider features such as propagation characteristics, power transmission levels, receiver sensitivity, coverage, and busy channel probability to estimate the delay for sending an emergency message across a route. The delay performance is evaluated in terms of the maximum distance between vehicles to receive a message that can be decoded, and the minimum number of hops required to cover a specific distance. We show that the delay using TVWS is less than the delay using DSRC in urban and suburban scenarios with non-line-of-sight, since TVWS provides a larger coverage. When channel congestion increases due to a high vehicular density, the increased access delay experienced by a DSRC network, based on CSMA/CA, directly impacts the performance of emergency applications. In that case, we propose the use of a TVWS network for the offloading of messages, to maintain the delay within the required values.

II. Comparison of DSRC and TVWS for emergency messages dissemination

To compare the multi-hop dissemination performance in urban (high density, low density) and suburban scenarios, we use Matlab simulations to obtain preliminary results and estimate the maximum distance between vehicles according to the receiver sensitivity specified in each technology. In the case of DSRC, we use an empirical model for path loss characterization in 5.9 GHz presented in [2], which consider line-of-sight (LOS) and NLOS paths. The propagation and pathloss in TVWS is modeled using a Hata-Davinson model with transmission in the 590 MHz [3], which has been suggested as an appropriate path loss model for accurately predict the TV signal reception for secondary users [4]. With the maximum distance estimation, we proceed to calculate the minimum number of hops required for sending an emergency message to cover a 500 m distance. Also, we calculate the end-to-end delay across the route, taking into consideration the channel contention using CSMA/CA, the propagation time, the transmission time, and the busy channel probability [5]. In the case of the TVWS network, we add an extra delay to represent the time for a vehicle (i.e., the secondary user) to detect if the channel is idle or busy before a transmission.

Figure 1 shows the receiver power versus distance between two vehicles (i.e., transmitter and receiver) for urban and suburban environments. Depending on the environment, the receiver sensitivity for each technology, being -95 dBm in DSRC [6] and -90 dBm in TVWS, is reached at different

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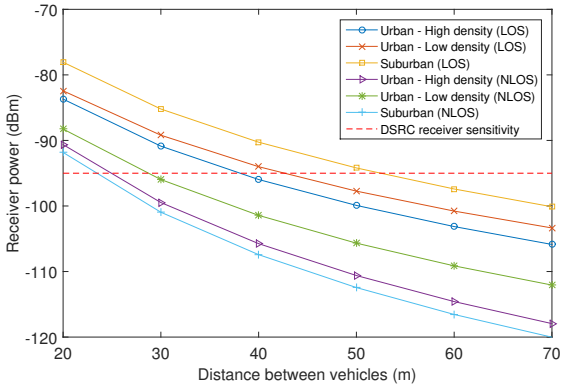
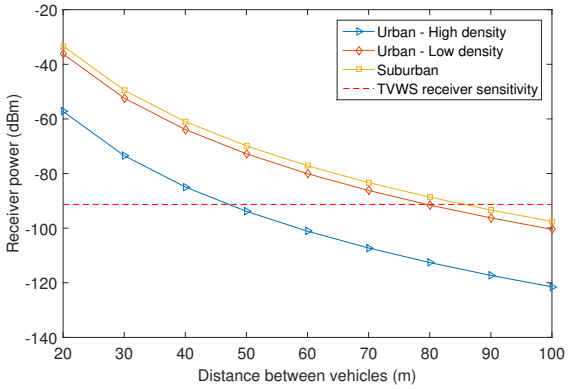
distances. In the case of DSRC (see Fig. 1a), the maximum distances between vehicles in LOS scenarios result in the range of 38 m to 68 m, which are higher than the 30 m achieved in NLOS scenarios. This is mainly due the fewer obstacles expected in LOS conditions. Conversely, Fig. 1b illustrates the maximum distance between vehicles when TVWS is used, being in the range of 47 m to 85 m, which is a reasonable range if one takes into consideration that transmission at 590 MHz has better obstacles penetration than transmissions in the 5.9 GHz band. Therefore, TVWS has a greater coverage than DSRC in both urban and suburban environment, with LOS and NLOS conditions.



(a) DSRC



(b) TVWS

Fig. 1: Receiver power vs. distance between vehicles

Regarding the minimum number of hops required to cover the 500 m target distance, Table I shows that sending an emergency message using TVWS requires less hops than using DSRC. Table II shows the estimated end-to-end delay when an emergency message is sent considering a busy channel probability of 30%. The results show that a TVWS network is a potential candidate to be an offloading network in V2V scenarios, specially when NLOS conditions are expected. However, the access delay in TVWS results to be high because a vehicle must detect if the channel is free of transmissions from the primary and other secondary users, before initiating a transmission. Using a spectrum sensing technique based on energy detection, the sensing time is calculated to be between 0.2 ms and 5 ms, which is greater than the 20 μs slot time in IEEE 802.11af, also referred to as White-Fi. However, the delay can become lower if the time spent on spectrum detection is reduced. An alternative could be to obtain the spectrum occupancy from a geo-location database, using a cellular-assisted long-range TVWS access architecture [7] to provide a control link, meanwhile TVWS is used for emergency message dissemination.

TABLE I: Minimum hops required to cover a specific distance

Scenario	TVWS	DSRC-LOS	DSRC-NLOS
Urban - High density (500m)	11	14	22
Urban - Low density (500m)	7	12	18
Suburban (500m)	6	10	21

TABLE II: End-to-end delay

Scenario	TVWS	DSRC-LOS	DSRC-NLOS
Urban - High density (500m)	12.5 ms	8.1 ms	12.8 ms
Urban - Low density (500m)	7.9 ms	7.0 ms	11.5 ms
Suburban (500m)	6.8 ms	5.8 ms	12.8 ms

III. Conclusions

In this article, we have proposed the use of a TV White Spaces (TVWS) access network for emergency messages dissemination in vehicular communications. The TVWS network could be a useful alternative to achieve a lower end-to-end delay in urban and suburban NLOS environments for V2V scenarios. This is due to the greater coverage distance between vehicles and the fewer hops needed for a multi-hop dissemination mechanism. The end-to-end delay estimation shows that there is an opportunity to improve the access delay in TVWS, if the time to estimate spectrum availability is reduced. We propose to explore the interworking of DSRC and TVWS for the offloading of messages, in particular to avoid transmission degradation and longer delays when the DSRC channel experiences congestion.

Acknowledgement

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