Leveraging on the Synergy between Visible Light Communication (VLC) and Radio Frequency (RF) to Enhance Intelligent Transport Systems (ITS)

Cedric Bammens*, Nina Slamnik-Kriještorac†, Vincent Charpentier†, Johann M. Marquez-Barja†
* University of Antwerp, Faculty of Applied Engineering - Department of Electronics-ICT, Belgium
† University of Antwerp - imec, IDLab - Faculty of Applied Engineering, Belgium

***Abstract*—Vehicular communication is a core technology of Intelligent Transportation Systems (ITS). Vehicle-to-vehicle (V2V) communication still needs to develop resilience, such that communication is safe and efficient, in time-critical applications. The radio-based systems, such as cellular V2X (C-V2X) and Dedicated Short Range Communication (DSRC), which are used classically for vehicular communication suffer from performance degradation in traffic scenarios where traffic is dense. In recent years, Line of Sight (LoS) technologies such as Visible Light Communication (VLC) are considered complementary technology to Radio Frequency (RF). VLC utilizes the light-emitting diodes (LEDs) headlamps and tail lights that are standard on modern vehicles to exchange information with the predecessor and subsequent vehicle. This work-in-progress paper highlights the need to combine RF and LoS technologies to improve the stability and reliability of V2V communication. Therefore, we discuss the different LoS and RF technologies, and we present the combinations that can be used for communication. Finally, we propose a hybrid strategy that combines the best properties of individual technologies.**

***Index Terms*—V2V, Intelligent Transportation Systems, C-V2X, Dedicated Short Range Communication, Vehicular Visible Light Communication, Autonomous Driving, Platooning, Cooperative adaptive cruise control**

I. Introduction

Autonomous vehicle platoons are an upcoming Intelligent Transport Systems (ITS) technology that will make it possible to drive semi-autonomous. Platooning is a strategy that consists of partially autonomous cars driving in a close formation with small gaps between vehicles while communicating with each other. Cooperative Adaptive Cruise Control (CACC) will maintain a constant distance from the predecessor and will use wireless communication to exchange information [1]. A platoon consists of multiple vehicles that will drive in close proximity in a single lane, following a leader vehicle. To maintain a platoon, vehicles will need to communicate and exchange information. Communication between vehicles needs to be as optimal as possible as an error can cause a safe system to become an unsafe one.

Current platooning proposals use RF communication based on DSRC or C-V2X. The DSRC technology is based on IEEE 802.11p [2] while the C-V2X standard is standardized by 3GPP [3]. When multiple platoons are in proximity on the same freeway, the RF network can become congested substantially increasing the possibility of packages being delayed or not being delivered. To solve this issue we can use VLC. VLC is a technology that utilizes light to transmit data to other vehicles. VLC can be used to send data by utilizing the unused wavelengths from 380nm to 780nm of the electromagnetic spectrum [4]. Due to the availability of a large spectrum, VLC will be able to transmit at high data rates. When using Vehicular Visible Light Communication (V-VLC) it is possible to use the front and tail lights of modern cars to communicate.

In this paper we compare both VLC and RF technologies. We also propose a basic hybrid strategy that will allow for the protocol to decide which communication technology needs to be used.

II. Comparing Communication Technologies

In Table I we discuss the advantages and disadvantages of RF and VLC. One of the main disadvantages of RF is the network congestion that takes place when large amounts of vehicles are in close proximity. When the network is congested there is a higher probability that packets will be severely delayed or completely dropped.

TABLE I: Communication Technologies.

	Advantages	**Disadvantages**
RF	Omnidirectional	Not secure
	Long Range	Network congestion
	Pass through object	Limited available spectrum
VLC	LoS Communication	Short range
	High data rates	Vulnerable to ambient light
	Low power consumption	Vulnerable to weather
	Unused spectrum	

The best solution can likely be found by combining VLC and RF. VLC can make up for RF's limited radio spectrum and the potential security attacks and RF can make up for the limited range of VLC.

III. Hybrid RF-VLC Solution

We propose an algorithm that will combine the previously mentioned technologies, VLC and RF, to ensure that we can utilize the advantages of both technologies and thus increase the reliability of the communication.

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Algorithm 1 Sending algorithm

```
procedure FIND_TECHNOLOGY(D)                    ▷ Destination D
    if D is Platoon then
        if update_rate < req_update_rate then
            result ← RF
        else if latency < req_latency then
            result ← RF
        else
            result ← VLC
        end if
    else if D is Outside then
        result ← RF
    end if
    return result
end procedure
```

IV. Results

A. Packet Delivery Ratio

Packet Delivery ratio (PDR) will measure the number of packages received compared to the number of packages expected to be received. We expect a Packet delivery rate of 100%. Figure 1 shows us that in the case of RF technologies, the PDR is decreasing when more vehicles are active. In contrast to the RF technologies, VLC and the hybrid strategies are able to maintain a higher PDR.

B. Latency

Latency expresses the time it takes for a packet of data to travel from a sender to a receiver. In Béchardergue et al. they find that the optimal latency of a package in a platoon is lower than 20ms [5]. In Figure 2 we compare the average latency of the technologies in two different scenarios, i.e. number of vehicles. When we compare the RF technologies we see that only IEEE 802.11p has a latency lower then the requirement. Comparing this to IEEE 802.11p and VLC using the strategy explained in III, the results show that this approach is able to maintain the required latency.

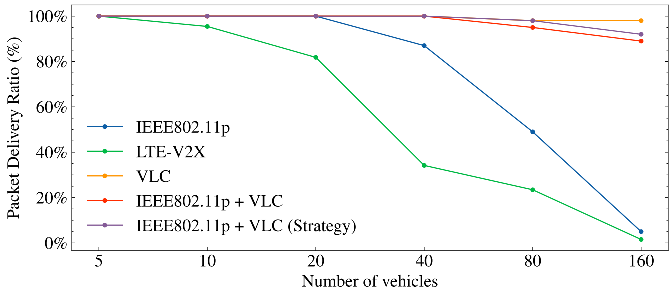

Fig. 1: Packet Delivery Ratio.

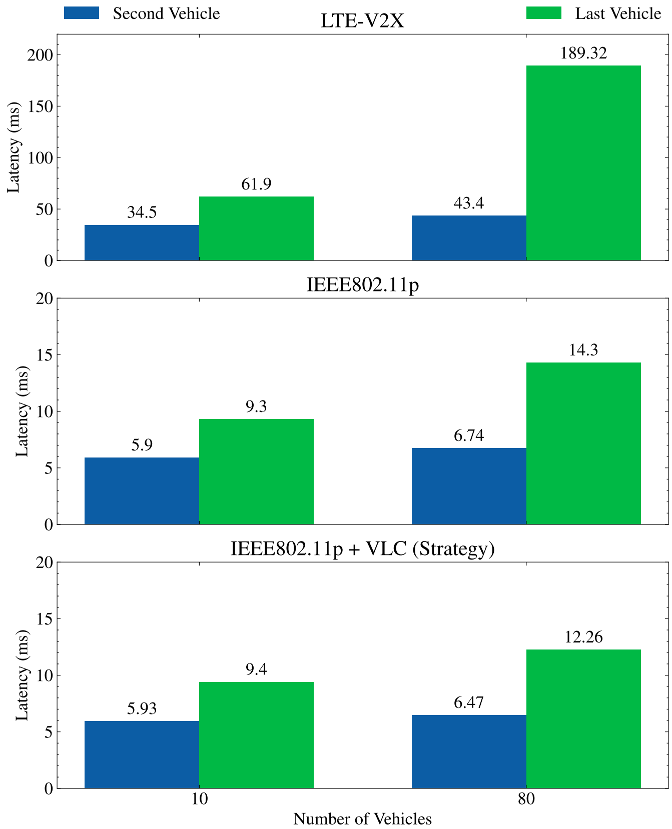

Fig. 2: Latency.

V. Conclusion and Future Work

In this work, we presented different communication technologies, i.e. IEEE 802.11p, LTE-V2X, and VLC, in different platooning scenarios, and we studied the scalability of these technologies when it comes to these scenarios. We then created a basic hybrid strategy that combines different technologies to improve overall communication reliability.

To compare these technologies, we simulated how each individual technology compares in a fast-moving environment such as a vehicular one.

As future work, we intend to improve the hybrid strategy so that the algorithm can make better decisions.

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