Poster: Evaluating the Potential of Mode 2(b) Resource Allocation in NR V2X Sidelink

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***Abstract*—New Radio (NR) Vehicle-to-Everything (V2X) technology promises safer and more efficient transportation by enabling direct communication between vehicles. Resource allocation in NR V2X Sidelink (SL) mode 2(a) faces challenges like the hidden node problem, prompting the proposal of cooperative resource scheduling, such as in mode 2(b). However, mode 2(b) definition is still in its infancy and lacks performance evaluation. In this paper, we present a cooperative resource scheduling scheme inspired by mode 2(b) to address these challenges. Through simulation-based evaluation, we demonstrate its potential, especially in virtual train coupling scenarios, offering insights to improve NR V2X communication.**

***Index Terms*—NR V2X Sidelink, Inter-UE coordination, Cooperative resource allocation, Multi-hop scheduling, Packet collision.**

I. Introduction

New Radio (NR) Vehicle-to-Everything (V2X) is an advanced technology initially designed to enable vehicles to communicate with various elements of the environment, including other vehicles, road infrastructure, and pedestrians. This technology offers numerous benefits in terms of safety, efficiency, and connectivity in transportation. Using advanced radio techniques, NR V2X enables fast and reliable information exchange between vehicles and the environment, contributing to traffic optimization and fostering efficient transportation systems. More recently, NR V2X has also been considered as a potential enabler of next-generation train control and monitoring systems [1].

Sidelink (SL) communication is a key component of NR V2X technology, enabling direct communication between nodes without the need for infrastructure involvement. This direct connection enables faster information exchange and response to environmental changes, resulting in more efficient traffic coordination and improved road safety.

NR V2X SL mode 2(a) with autonomous resource selection represents one of the standardized iterations of this technology, allowing nodes to automatically select optimal resources for communication based on current traffic and environmental conditions [2]. The resource sensing window in mode 2(a) allows User Equipments (UEs) to detect resource reservations by other neighboring nodes. This autonomous feature enables more efficient and reliable communications, reducing the need for manual adjustments and optimizing resource utilization.

However, challenges such as the hidden node problem still exist in mode 2(a) scheduling. The hidden node problem occurs when simultaneous transmissions from two or more UEs sharing the same resources cause packet collisions that prevent a receiving UE from decoding data from either transmitting end. A recent extension to mode 2(a), namely mode 2(b), has been proposed to address this issue [3]. In mode 2(b) scheduling, UEs can cooperate with each other by sharing system information, including selected resources by neighboring nodes and other channel conditions.

However, the definition of this scheduling mode is still under discussion and, to the best of our knowledge, its performance is yet to be evaluated. To fill this gap, in this paper we propose a cooperative resource scheduling scheme based on the inter-UE coordination mechanism presented in mode 2(b) [4]. We evaluate the performance of this implementation and demonstrate its potential by considering the use case of virtual train coupling [1], [5].

II. Mode 2(b) Resource Allocation

Consistent with mode 2(b), in our proposed strategy, UEs share information about selected resources, including those selected by other UEs. However, determining the resource information about which "other" UEs to share is a key challenge. To this end, we consider the hidden node problem and its underlying causes.

In particular, each transmitting UE includes in its periodic broadcast messages the list R of resources occupied by the node itself and by other one-hop neighboring nodes, i.e., detected during the sensing window. This is inspired by the fact that a UE typically receives the strongest signals from its neighboring UEs, and thus a lack of knowledge about resource occupancy at the UE's neighbors can cause collisions around the UE.

Additionally, there may be UEs that are too far away from a target UE for it to successfully decode their broadcast signals. However, these UEs could still cause interference to the target UE, potentially leading to collisions if they select the same resources as other nearby UEs. To address such situations, our solution proposes to extend the range of awareness beyond the one-hop neighborhood to further manage the interference as explained above. In particular, each UE can additionally broadcast the unified lists of occupied resources received from

Algorithm 1 One-hop & Two-hop resource scheduling

H: boolean enabling the extended two-hop scheduling
R: list of resources occupied by the target UE itself and by its one-hop neighbors (detected during the sensing window)
N: list of one-hop neighbors of the target UE
M: periodic broadcast message

```
1: M ← init()
2: if BroadcastEvent then
3:     M.append(R)
4:     if H is true then
5:         R_ext ← {∪_{k∈N} R_k} − R
6:         M.append(R_ext)
7:     end if
8:     broadcast(M)
9: end if
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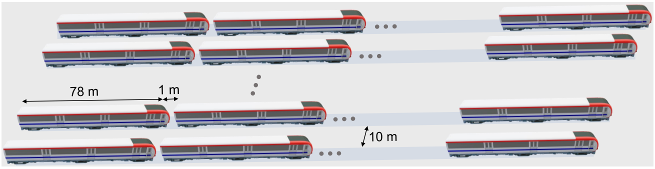

Figure 1. Illustration of the train depot scenario.

its one-hop neighbors, i.e., the union of R_k, for all one-hop neighbors k of the target UE. We refer to this proposed scheme as two-hop scheduling.

Pseudocode is provided in Algorithm 1, which explains both one-hop and two-hop scheduling on a generic UE. In particular, a transmitting UE appends the list of resources R occupied by the UE itself and by other one-hop neighboring UEs, as sensed during the sensing window (line 3). If the extended two-hop scheduling scheme is enabled (line 4), the UE additionally appends the unified list of occupied resources R_{ext} received from its one-hop neighbors (lines 5 and 6). The receiving nodes can then use this information to filter the list of available resources when scheduling new transmissions.

To evaluate the potential of both our one-hop and two-hop mode 2(b) implementations, we focus on the *busy depot/junction* scenario described in [5], where there are 10 parallel tracks with one static train on each track. Each train is a sequence of 10 wagons/consists, each 78 m long, as shown in Figure 1. Communication is established across all the consists on all the tracks to form virtually coupled trains. The distance between the tracks is 10 m and the distance between consists is 1 m.

UEs transmit in the 5.9 GHz frequency band with a spectral power density of 13 dBm/MHz. A bandwidth of 10 MHz with a Modulation and Coding Scheme (MCS) of 11 is assumed. A noise figure of 9 dB is assumed at the receiver. The channel model used is WINNER+, scenario B1 [5]. Finally, for simplicity, it is assumed that fixed-size packets of 1000 Byte are periodically generated every 100 ms by each UE.

We have extended the NR V2X mode 2(a) MATLAB model described in [6] to simulate the proposed mode 2(b) scheduling mechanisms. We compare the performance of both mode 2(b) approaches with two benchmark solutions: the legacy mode 2(a) and a "best case" scenario. The latter is derived based on the outcome of mode 2(a) and by simply changing the status of hidden-node collisions to successful transmissions. According to this description, the "best case" scenario is just an optimistic indicator that may not even be achieved in practice.

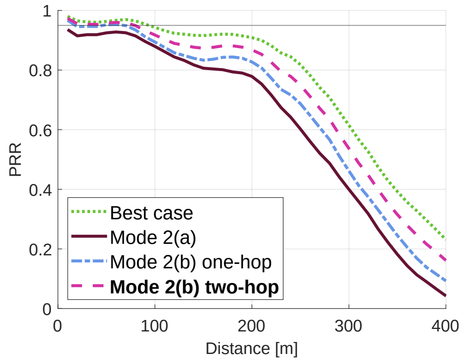

Figure 2. PRR for different schemes.

Figure 2 shows the performance of the different schemes in terms of Packet Reception Ratio (PRR) when varying the transmitter-receiver distance. It can be observed that mode 2(b) scheduling significantly improves the PRR when compared to mode 2(a). It can also be observed that the extended two-hop resource scheduling approach improves the PRR by up to 27 % compared to the one-hop method and it is the closest to the "best case" scenario.

III. Conclusion

In this paper, we explored the potential effectiveness of cooperative resource allocation for New Radio (NR) Vehicle-to-Everything (V2X) Sidelink (SL) to address the hidden-node problem. We proposed two mode 2(b) resource scheduling schemes, which allow nodes to broadcast information about resources occupied by their one and two-hop neighbors.

As future work, we plan conduct a more extensive performance evaluation of cooperative resource scheduling under more realistic scenarios (e.g., variable packet size, realistic train mobility). To this end, the impact of packet overhead on various Key Performance Indicators (KPIs) should be investigated.

Acknowledgments

Supported by the Luxembourg National Research Fund INTER/ANR/22/17192457/CANDI.

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