setup with the SUMO traffic simulation did not provide reliable results for fuel consumption and CO2 emissions. We detected inconsistencies in these measurements where the baseline achieved worse results than any of the proposed mechanisms. In a detailed investigation of the root causes, we found that the inconsistencies stem from calculation flaws in SUMO as the fuel consumption and CO2 emission values are set to 0 ml/s and 0 mg/s per default whenever a vehicle decelerates. Therefore, we omitted these measurements and did not report the results. An adaptation of the calculation regarding these values could help to provide meaningful measurements in the future.

Fourth, we investigated our mechanisms using only one type of vehicles. Having heterogeneous platoons composed of vehicles with individually different characteristics—like different acceleration/brake coefficients, size, weight, or drag coefficients—establish additional constraints. The same applies for individual preferences of drivers as well as heterogeneous goals, as often present in SISSY systems [2]. Integrating those perspectives requires more flexibility in the compensation mechanisms and is part of our future work.

Lastly, we acknowledge that the taxonomy could be changed or extended. In this paper, we present our taxonomy mainly motivated by considering ideas from research about social sciences [27] and organ donation [28]. The taxonomy supports researchers in the platooning area in designing their approaches by tackling one of the main issues: the unbalanced distribution of the advantages of platooning. Moreover, we discussed how to apply the taxonomy in other SISSY use cases; however, we miss a proof of concepts in those other domains so far. As this requires customization of the implementation actions of the taxonomy for the specific implementation for each application domain, this is part of our future work. The application in other SISSY systems can trigger a revision of the taxonomy for a better generalization of our claims. Still, we believe that in the current state, the taxonomy can provide guidelines for balancing the benefits in SISSY systems to support system designers and application developers.

8. Conclusion

Integrating autonomous resources into interacting systems can be challenging, especially in scenarios in which some participants might experience negative impacts due to the integration [2, 4]. In previous work [6], we categorize coordination mechanisms for this integration into (i) selfish behavior, (ii) altruistic behavior, (iii) negotiation, (iv) enforcement of central decision making, and (v) rewards/incentives. In this paper, we derived a taxonomy of compensation-centered incentive models. In a case study in the platooning domain, we analyzed the fairness of several compensation methods as well as the impact of the performance of system elements that are not integrated into different traffic situations using simulations. The evaluation of our proposed compensation mechanisms has shown that all mechanisms distribute negative effects—in the platooning case-study fewer benefits—equally among all vehicles in a platoon. However, depending on the scenario, the mechanisms might disturb other traffic participants. Further, we investigated that increasing surrounding traffic decreases the overall traffic speed as well as introduces additional time loss. Finally, an increased platoon speed can counter this effect by decreasing the time loss. Based on the study, we propose several challenges related to the applicability of the mechanisms for compensation, the definition of fairness metrics, integration of the environment, the dynamic choice of the incentive model, and how to integrate multiple incentive schemes simultaneously.

Currently, we performed a case study with a homogeneous set of vehicles. Introducing heterogeneous platoons composed of vehicles with individually different characteristics as well as individual preferences of drivers with heterogeneous goals will require more flexibility in the compensation mechanisms. This is part of our future work in the platooning scenario. As additional future work, we plan to apply our taxonomy in further use case domains to show its transferability. Using those experiences, we then formulate generic compensation-based approaches for integrating the aspect of incentivization into the reasoning process for system integration. This also results in a “toolset” of such mechanisms that can be used in several domains. We plan to complement this by an approach for modeling incentives and compensation.

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