Coordinated Group Cycling for Commuting

Lukas Stratmann
stratmann@ccs-labs.org
TU Berlin, Germany

Julian Heinovski
heinovski@ccs-labs.org
TU Berlin, Germany

Falko Dressler
dressler@ccs-labs.org
TU Berlin, Germany

ABSTRACT

A crucial step for reducing emissions in the transport sector is the shift towards public transportation and bicycling. However, due to the lack of perceived safety, people are reluctant to commute by bicycle. A potential solution to this problem could be group cycling, allowing cyclists to form a group with others in order to ride together. Depending on local traffic laws, such groups allow for cycling next to each other and for special rights for intersection crossing. In this paper, we outline how group cycling commutes may be coordinated using communication capabilities of contemporary smartphones. We showcase how group cycling can reduce waiting times and, thus, improve ride comfort and safety in a simulation-based case study.

CCS CONCEPTS

• **Networks** → **Application layer protocols**; **Network simulations**.

KEYWORDS

Vehicular networking, vulnerable road users, intelligent transportation systems

ACM Reference Format:

Lukas Stratmann, Julian Heinovski, and Falko Dressler. 2024. Coordinated Group Cycling for Commuting. In *The 30th Annual International Conference on Mobile Computing and Networking (ACM MobiCom '24), November 18–22, 2024, Washington D.C., DC, USA.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3636534.3697429

1 INTRODUCTION

To reduce emissions in the transport sector, a crucial step is to shift the modal split away from car use and towards walking, bicycling, and public transportation [4, TS.5.3]. Given that 32 % of people drive a car even for short trips between 1 km and 3 km, and 43 % do so for trips between 3 km and 5 km,[1] we see that there is significant room for improvement. An important factor that makes people reluctant to commute by bicycle is a lack of perceived safety [14]. Building fault-tolerant infrastructure helps [12], but this tends to be a slow process in many places [10].

A possible solution to this problem meanwhile could be *group cycling*, where cyclists meet up with others to form a group in order to commute together. If such a group is large enough, depending on local traffic laws, they can then cycle next to each other on the road. In some countries, large cohesive groups of cyclists[2] even gain the special right of counting as one vehicle when crossing an intersection, i.e., followers may continue crossing even if the traffic light has turned red in the meantime. It has been reported that people with experience in group cycling have a reduced level of perceived risk [13].

A notable precedent for this idea is the Critical Mass, which is a monthly bicycling event with sometimes thousands of cyclists that has been observed in hundreds of cities worldwide since 1992 [2]. Several individuals have in this context independently and on several occasions expressed the wish for commuting by critical mass. Furthermore, in many cities one can already find schedules and routes for a so-called bike bus or bicibús.[3] These are typically organized to allow children to safely ride their bicycles to school at least once per week. However, in order to make group cycling a viable option for daily commutes for everybody, further coordination will be required to increase availability.

In this paper, we outline how *group cycling* commutes may be coordinated using communication capabilities of modern smartphones. To this end, we propose to use group cycling to help cyclists to form a group in order to commute together. We design a protocol for coordination and assess its effects in a simulative case study. In particular, we showcase how group cycling can reduce waiting times and, thus, improve ride comfort. We see our solution as an important component to pave the way for the modality shift from cars to bicycles.

2 RELATED WORK

Group cycling, or bicycle platooning in the context of vehicle-to-everything (V2X) communication, has already been the subject of a handful of publications. Céspedes et al. [3] propose group cycling for an improved cycling experience on bicycle infrastructure, motivated by overflowing infrastructure and traffic congestion of cyclists at intersections. To accomplish this, they developed a prototype that makes use of bicycles equipped with cooperative adaptive cruise control (CACC) as well as a haptic and visual user interface. However, for the purpose of our proposed group cycling, longitudinal distance control or string stability [11] and therefore CACC will likely not be strictly required. In a similar way, Yang and Griggs [15] also speak of overflowing bicycle infrastructure and assume CACC-enabled e-bikes for their simulations. Their motivation is an unsignalized intersection that is prone to accidents because other traffic participants will try to squeeze through an already rarely interrupted stream of bicyclists. This is an issue we

[1] Survey among citizens living in German cities with more than 500 000 inhabitants (excluding Berlin): https://tu-dresden.de/bu/verkehr/ivs/srv/ressourcen/dateien/SrV2018_Tabellenbericht_Oberzentren_500TEW-_flach.pdf

[2] § 27 StVO in Germany: ≥ 16 cyclists, § 68 StVO in Austria: ≥ 10 cyclists

[3] e.g., https://bicibus.de or https://bicibus.eu/en/

ACM MobiCom '24, November 18–22, 2024, Washington D.C., DC, USA

ACM ISBN 979-8-4007-0489-5/24/11
https://doi.org/10.1145/3636534.3697429

rarely observe in Berlin, and it highlights the wide range of issues in bicycle infrastructure in different communities.

Beecham and Wood [1] analyzed the cycling behavior of the users of a bike sharing service. They found that group cycling could already be observed in 3 % of all journeys, and while 46 % of group journeys happen on weekends, they did also discover an increase in group activity during commuting times. An overview of how cyclists behave when cycling in a group, especially concerning safety, is given by Heeremans et al. [7].

Regarding cars and trucks, platooning is not as young a research field as it is for cyclists. For example, different modes of coordinating a platoon have found consideration by Hall and Chin [5], who have their vehicles wait and accumulate before entering a freeway as a platoon, or Heinovski and Dressler [8], who find platoon members en route on a freeway. Even more closely related to the bicycle use case, Hardes and Sommer [6] consider platoon formation among cars stopped at red lights in an urban setting.

3 COORDINATED GROUP CYCLING

We propose to use *group cycling*, where cyclists meet up with others to form a group in order to commute together, to pave the way for the modality shift from cars to bicycles. Conceptually, people would meet up with others to commute by bicycle – either based on a public-transportation-like schedule or spontaneously for critical segments of their commute. If such a group is large enough, depending on local traffic laws, they can then cycle next to each other on the road. In some countries, large cohesive groups of cyclists even gain the special right of counting as one vehicle when crossing an intersection, i.e., followers may continue crossing even if the traffic light has turned red in the meantime. Group cycling on the road might come with a range of possible benefits: better visibility compared to cycling behind a row of parked vehicles; reduced risk of accidents during right-turns because drivers would have to cross another car lane; safer overtaking maneuvers by car drivers because now lane changes are not only legally, but also physically necessary; increased comfort, e.g., due to a smoother surface, straighter paths, and fewer obstacles; fewer puddles after rain and less ice after snow; and the social benefit of physical activity in a group. We imagine at least two possible approaches for coordinating a group cycling commute:

(a) Routes and departure times can be pre-planned like a bus schedule. Group cycling is used for the bike buses mentioned above and has the advantage that one might start establishing recurring groups with just a very small number of people, without the need for high market penetration of any new technology. A mobile app with a central server for finding and joining existing groups or creating new ones should be relatively straight-forward.

(b) Groups form spontaneously. For example, I might be approaching a segment of my trip to work that feels dangerous – e.g., a cycle lane having become barely passable due to ice and snow. In that case, I would rather use the road, but the car traffic is fast and intimidating. However, especially in cities chances will be high that other cyclists are going to face the same dilemma within a short time span. If there was a convenient way to indicate to one another the interest to form a group, maybe a sufficient number of interested cyclists can be found.

All coordination is performed using wireless communication technologies offered by modern smartphones. This could likely be achieved either communicating over the Internet or using Bluetooth Low Energy (BLE) for device-to-device (D2D) communication. Here, an approach similar to platooning of passenger cars can be used, where vehicles search for potential platooning opportunities en route. Optionally, the cyclists could wait for others to form a group before entering the dangerous road segment.

In our proposed protocol used for Section 4, each cyclist transmits a group status beacon once per second, which contains the type of the beacon message, a unique identifier of the group leader, and a timestamp of when the cyclist has last directly or indirectly heard from the leader. The unique identifier is used in simulation to allow followers to catch up and adjust to the speed of the leader. In the real world, this process could likely simply happen visually. In general, at least an indication of the leader's geolocation for the duration of the group ride is required.

The timestamp is important for re-establishing a group if the leader disappears after a given timeout (5 s in our case), e.g., because they left the group or the group split up. In that case, the group formation and leader election restarts. When a cyclist is not yet assigned to a group, they will transmit group interest beacons containing the current road segment and distance moved on it (similar to a geolocation). If received by another interested cyclist, this recipient will either accept and start transmitting group status beacons as the leader, or, if the other cyclist is closer to the destination, send a correction beacon.

4 CASE STUDY

In this case study, we demonstrate the potential benefit in ride comfort if cyclists move together as a group and are allowed to cross intersections like one cohesive vehicle. We use Veins, OMNeT++, and SUMO as our simulation framework. As a reference scenario, we model a straight street of 2.4 km in length based on Wilhelmstraße in Berlin; a small sketch of it is shown in Figure 1. This street has 13 traffic lights at an average distance of 179 m (in simulation uniformly ±20 m) and would be a good candidate for group cycling, since for most of its length the cycling infrastructure consists of painted cycle lanes overlapping with the door zone of parked cars (cf. [12]), and at one intersection the cycle lane is routed in between two driving lanes. It is common on this road for car drivers not to keep the legally required distance to cyclists when they overtake them. Given the high number of traffic lights, it is furthermore common to observe cyclists running red lights. Reducing the amount of time cyclists have to spend waiting at traffic lights may therefore in itself contribute to safety.

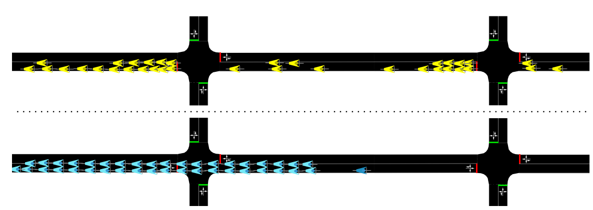

Figure 1: Many cyclists crossing signalized intersections, either individually (top) or as a cohesive group (bottom).

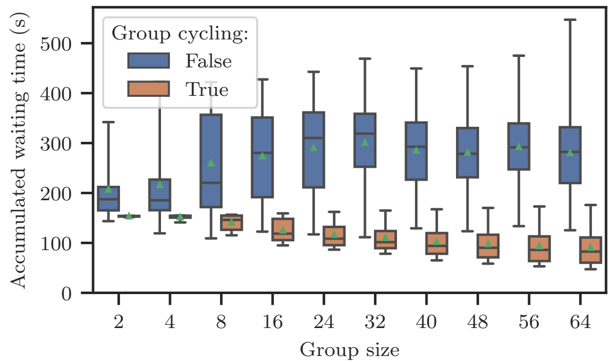

Figure 2: Accumulated waiting time per cyclist on a street with 13 traffic lights. The whiskers show min. and max.

We compare groups of 2 and up to 64 cyclists all starting in the same group formation in rows of two at the beginning of the street. If group cycling is disabled, they will each try to move at their own pace and in all cases stop at a red light. The distribution of individual preferred maximum speeds is set according to the work of Karakaya et al. [9]. If group cycling is enabled, all cyclists of one simulation run will move as one group. Groups are being maintained by group status beacons exchanged between members in 5 s intervals. Each condition is repeated 10 times.

When a bicycle reaches the end of the street, we record its accumulated waiting time, i.e., how many seconds it had to stand still. These waiting times are shown for each group size and for group cycling enabled or disabled in Figure 2. For the case that there is no group cycling, we see that the waiting time has a large spread from between 100 s and 400 s with 8 cyclists starting at the same time, and reaching above 500 s for 64 cyclists. Figure 1 shows how waiting times can accumulate at consecutive red lights when queues start to form and cyclists in the back are being delayed on their way to the next intersection. Since our simulation only allows two cyclists side by side, chances for overtaking are limited, which could in turn make the scenario representative of a crowded cycling lane. This may also in part explain why the median waiting time does not appear to increase beyond groups of 32, as we see long queues starting to form behind small clusters of slower cyclists. In contrast, when group cycling is enabled, the maximum waiting time is only experienced by cyclists at the very front of the group. In Figure 2, this maximum is mostly constant because the desired maximum speed of the leader is set to $4.38\,\mathrm{m\,s^{-1}}$ (i.e., the average in [9]). The larger a group becomes, the lower the accumulated waiting time is for most of its participants.

5 CONCLUSION AND FUTURE WORK

Group cycling as a form of commuting has the potential to bridge the gap towards a healthier modal split in people's mobility. Convenient means for coordinating groups are required for such commutes to find broad application. We have laid out how this may be accomplished and demonstrated one benefit, namely an improved ride comfort due to reduced waiting times, in a simulation study.

In future work, it will be necessary to take a closer look at how groups can be formed effectively, especially in the case of spontaneous group formation. While some concepts of car platooning can certainly be applied, bicycle groups come with some unique challenges and opportunities. For example, the amount of time cyclists are willing to wait for new group members will be influenced by a range of factors such as weather or the perceived danger of the road and for how much distance they expect to confront it. Regarding opportunities, cyclists will be less prone than cars to blocking other traffic participants while they wait.

ACKNOWLEDGMENTS

This work has been supported by the Federal Ministry of Education and Research (BMBF, Germany) within the 6G Platform under Grant 16KISK050.

REFERENCES

[1] Roger Beecham and Jo Wood. 2014. Characterising group-cycling journeys using interactive graphics. *Elsevier Transportation Research Part C: Emerging Technologies* 47 (Oct. 2014), 194–206. https://doi.org/10.1016/j.trc.2014.03.007

[2] Susan Blickstein and Susan Hanson. 2001. Critical mass: forging a politics of sustainable mobility in the information age. *Transportation* 28 (Nov. 2001), 347–362. https://doi.org/10.1023/a:1011829701914

[3] Sandra Céspedes, Juan Salamanca, Alexis Yáñez, and Daniel Vinasco. 2019. Group Cycling Meets Technology: A Cooperative Cycling Cyber-Physical System. *IEEE Transactions on Intelligent Transportation Systems* 20, 8 (Aug. 2019), 3178–3188. https://doi.org/10.1109/tits.2018.2874394

[4] Felix Creutzig, Joyashree Roy, Patrick Devine-Wright, Julio Díaz-José, Frank W. Geels, Arnulf Grubler, Nadia Maïzi, Eric Masanet, Yacob Mulugetta, Chioma Daisy Onyige, Patricia E. Perkins, Alessandro Sanches-Pereira, and Elke Ursula Weber. 2022. Demand, services and social aspects of mitigation. In *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, 503–612. https://doi.org/10.1017/9781009157926.007

[5] Randolph Hall and Chinan Chin. 2005. Vehicle sorting for platoon formation: Impacts on highway entry and throughput. *Elsevier Transportation Research Part C: Emerging Technologies* 13, 5 (Dec. 2005), 405–420. https://doi.org/10.1016/j.trc.2004.09.001

[6] Tobias Hardes and Christoph Sommer. 2019. Dynamic Platoon Formation at Urban Intersections. In *IEEE LCN 2019, Poster Session.* IEEE, Osnabrück, Germany. https://doi.org/10.1109/lcn44214.2019.8990846

[7] Olaf Heeremans, Elisabeth Rubie, Mark King, and Oscar Oviedo-Trespalacios. 2022. Group cycling safety behaviours: A systematic review. *Elsevier Transportation Research Part F: Traffic Psychology and Behaviour* 91 (Nov. 2022), 26–44. https://doi.org/10.1016/j.trf.2022.09.013

[8] Julian Heinovski and Falko Dressler. 2024. Where to Decide? Centralized vs. Distributed Vehicle Assignment for Platoon Formation. *IEEE Transactions on Intelligent Transportation Systems* (2024). https://doi.org/10.1109/TITS.2024.3426615

[9] Ahmet-Serdar Karakaya, Ioan-Alexandru Stef, Konstantin Köhler, Julian Heinovski, Falko Dressler, and David Bermbach. 2023. Achieving Realistic Cyclist Behavior in SUMO using the SimRa Dataset. *Elsevier Computer Communications* 205 (May 2023), 97–107. https://doi.org/10.1016/j.comcom.2023.04.015

[10] G. Mattioli, C. Roberts, J. K. Steinberger, and A. Brown. 2020. The political economy of car dependence: A systems of provision approach. *Energy Research & Social Science* 66 (Aug. 2020). https://doi.org/10.1016/j.erss.2020.101486

[11] Steven E. Shladover, Charles A. Desoer, J. Karl Hedrick, Masayoshi Tomizuka, Jean Walrand, Wei-Bin Zhang, Donn H. McMahon, Huei Peng, Shahab Sheikholeslam, and Nick McKeown. 1991. Automated Vehicle Control Developments in the PATH Program. *IEEE Transactions on Vehicular Technology* 40, 1 (Feb. 1991), 114–130. https://doi.org/10.1109/25.69979

[12] Rul von Stülpnagel and Heiko Rintelen. 2024. A matter of space and perspective – Cyclists', car drivers', and pedestrians' assumptions about subjective safety in shared traffic situations. *Elsevier Transportation Research Part A: Policy and Practice* 179 (Jan. 2024). https://doi.org/10.1016/j.tra.2023.103941

[13] Simon Washington, Narelle Haworth, and Amy Schramm. 2012. Relationships between Self-Reported Bicycling Injuries and Perceived Risk of Cyclists in Queensland, Australia. *Transportation Research Record (TRR)* 2314, 1 (Jan. 2012), 57–65. https://doi.org/10.3141/2314-08

[14] Meghan Winters, Gavin Davidson, Diana Kao, and Kay Teschke. 2011. Motivators and deterrents of bicycling: comparing influences on decisions to ride. *Transportation* 38 (Jan. 2011), 153–168. https://doi.org/10.1007/s11116-010-9284-y

[15] Oliver Yang and Wynita. M. Griggs. 2021. Connected e-Bicycle Platoons at Unsignalised Intersections. In *IEEE ITSC 2021.* IEEE, Indianapolis, IN, 1875–1882. https://doi.org/10.1109/itsc48978.2021.9564869