SOE 10: Traffic Dynamics, Urban and Regional Systems I

Time: Wednesday 15:00–16:30 Location: ZEU 260

SOE 10.1 Wed 15:00 ZEU 260

The random walks of ridepooling — •Benjamin Köhler[1], Philip Marszal[1], Marc Timme[1,2], and Malte Schröder[1] — [1]Chair for Network Dynamics, Institute of Theoretical Physics & Center for Advancing Electronics Dresden (cfaed), TU Dresden — [2]Lakeside Labs, Klagenfurt, Austria

Ridepooling services have become an increasingly attractive mobility option in urban areas. As users issue requests for transport, ridepooling vehicles drive through the road network, continually adjusting their routes to pick up and deliver users with similar trips in shared rides. The quality of such services strongly depends on the dynamics of evolving vehicle routes, which collectively emerge from the interactions of the vehicles and requests. So far, theories of ridepooling services have focused on macroscopic and mean-field dynamics, neglecting the underlying microscopic route evolution. Here we analyze the structure and dynamics of these random routes in the limit of high service efficiency. We find an emerging random walk of a route that is specified not only by the current location of the vehicle, but also by the route planned ahead to pick up or drop off passengers who are currently transported in the vehicle or have already requested a ride. We map this process to an ordinary Markov random walk on an abstract graph whose nodes represent the shortest paths of the original street network. We thereby identify emerging routing patterns and evaluate their implications for the ridepooling service. Understanding these random route processes may help to further advance service quality, for instance by designing stop networks and routing algorithms to maximize flexibility.

SOE 10.2 Wed 15:15 ZEU 260

Scaling laws of ridepooling random routes — Philip Marszal, Marc Timme, and •Malte Schröder — Chair for Network Dynamics, Institute of Theoretical Physics & Center for Advancing Electronics Dresden (cfaed), TU Dresden

On-demand ridepooling services are emerging as a new form of urban mobility across the globe. Users request a trip, are assigned to one of the available ridepooling vehicles, and then transported in a shared ride. Despite the complex dynamics of these systems, their efficiency and service quality is characterized by universal macroscopic scaling laws. However, the scaling laws are typically derived from mean-field calculations neglecting the details of the microscopic dynamics of individual vehicles. Here, we analyze these microscopic dynamics in terms of the *ridepooling random routes* of the vehicles as a new type of random walk process. In contrast to standard random walks, random routes are characterized by a pre-planned route of scheduled stops evolving as new requests are added to the route and users are picked up and delivered. We identify multiple timescales emerging in the routing dynamics and quantify the resulting structure of the random routes in terms of their persistence and diffusion properties. Importantly, microscopic scaling laws of the random route properties directly give rise to macroscopic scaling laws of the overall system efficiency. This perspective of microscopic random routes in ridepooling services may help to better understand their complex dynamics and scaling laws and optimize these services by identifying recurrent route patterns or adjusting allowed stop locations to guide the self-organized routing dynamics.

SOE 10.3 Wed 15:30 ZEU 260

Bi-modal transport: united against the private car — Puneet Sharma, •Knut Heidemann, Helge Heuer, Steffen Mühle, and Stephan Herminghaus — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen, Germany

Motorized individual traffic leads to a prohibitive waste of energy and other resources. We show that combining a line service with a fleet of ride-pooling shuttles may provide on-demand door-to-door service with a service quality superior to customary public transportation, while at the same time consuming only about 20% of the energy a corresponding fleet of private cars would require, and with a road traffic volume reduced by orders of magnitude. We find favorable performance not only in urban, but also in rural settings. While the first part relies on a mean-field model and a simple model geometry, in part two, we test our results by simulations of real-word scenarios.

SOE 10.4 Wed 15:45 ZEU 260

Demand-driven design of bike path networks — •Christoph Steinacker[1], David-Maximilian Stroch[1], Marc Timme[1,2], and Malte Schröder[1] — [1]Chair for Network Dynamics, Institute of Theoretical Physics & Center for Advancing Electronics Dresden (cfaed), TU Dresden — [2]Lakeside Labs, Klagenfurt, Austria

Cycling is crucial for sustainable urban transportation. Promoting cycling critically relies on a sufficiently developed bicycle infrastructure. In general, designing efficient infrastructure networks constitutes a highly complex problem that requires balancing multiple, often opposing, constraints. In particular, bike path networks need to enable both safe and direct travel for all cyclists with an often strongly limited budget and strong competition for limited road space.

Here, we present a framework to create families of efficient bike path networks [1]. We reverse the network formation process and iteratively remove bike paths from an initially complete bike path network. In addition, we continually update cyclists' route choices, explicitly taking into account the cyclists' demand and their safety and convenience preferences. In this way, we create a sequence of networks that is always adapted to the current cycling demand.

We illustrate the applicability of this demand-driven planning scheme with empirical infrastructure and demand data. The framework may thus enable us to study properties of the structure of efficient bike path networks across cities and quantify the impact of different demand distributions.

[1] Steinacker *et al.*, Nat. Comput. Sci. **2**, 655-664 (2022).

SOE 10.5 Wed 16:00 ZEU 260

Does unorganized outperform organized public transport? — •Kush Mohan Mittal[1], Malte Schröder[1], and Marc Timme[1,2] — [1]Chair for Network Dynamics, Institute of Theoretical Physics & Center for Advancing Electronics Dresden (cfaed), TU Dresden — [2]Lakeside Labs, Klagenfurt, Austria

Organized public transport is commonly assumed to be more efficient compared to unorganized or self-organized mobility services that often prevail in the Global South. Here, we analyze OpenStreetMap route data from a total of 4500 routes of both organized and unorganized public transport services in more than 40 cities across the globe. Dividing bus routes into smaller segments and comparing their length to the shortest path distance between the segments endpoints, we find that segments more central in a route consistently exhibit substantially less detour than those towards the ends of the route. This non-homogeneous detour distribution occurs universally, irrespective of whether a city is dominated by organized or unorganized transport. These structural properties of the routes have significant implications for the attractiveness of public transport, as people living in the outskirts at the end of the routes typically both have overall longer trips and experience more (relative) detours than people living in the city center. Intriguingly, we provide quantitative evidence that decentrally self-organized transport routes typically exhibit less heterogeneity and at the same time achieve smaller overall detours. Moreover, they may also outperform organized transport in terms of social accessibility and route interconnectivity.

SOE 10.6 Wed 16:15 ZEU 260

Fix or flex? How ridepooling complements public transport — •Verena Krall[1], Marc Timme[1,2], and Malte Schröder[1] — [1]Chair for Network Dynamics, Institute of Theoretical Physics & Center for Advancing Electronics Dresden (cfaed), TU Dresden, Germany — [2]Lakeside Labs, Klagenfurt, Austria

Urban mobility is changing rapidly, not least due to the global rise of on-demand ridepooling services. In contrast to classic public transport with fixed lines and schedules, these new services offer a flexible shared transport with stops and routes determined by demand. This flexibility might attract new users to shared transport and offer higher accessibility to mobility in districts with poor public transport infrastructure. However, a complete shift from fixed line-based to flexible on-demand services would be detrimental, increasing congestion and wasting existing infrastructure. How can the two different service types complement each other to improve public transport? We find that the service quality is optimal if both line-based and on-demand transport are available. Additionally, we investigate adaptations of public transport networks and find that replacing inefficient lines step-by-step with on-demand vehicles may strongly reduce the overall costs. Applying our approach to empirical public transport networks, we identify lines that should be replaced with on-demand service. Our study shows how the combination of classic line-based with on-demand mobility may contribute to a public transport system that is both sustainable and user-friendly.