

Buses on demand

It is extremely difficult to get around in rural areas without a car of your own, either due to a lack of public transport or because scheduled buses are infrequent. That is why a team led by physicist **Stephan Herminghaus**, Director at the **Max Planck Institute for Dynamics and Self-Organization** in Goettingen, have developed the EcoBus, a system that lets customers order a bus directly to their front door. The special thing about it is that, unlike other on-call systems, rather than poaching customers, the EcoBus will augment existing public transport services.

TEXT **TIM SCHRÖDER**

Oh man, I've really hit the jackpot today," exclaims the young man who boards the bus at the outskirts of Clausthal, "I only had to wait three minutes!" His car is currently in the workshop, so for the past few days he has been catching the EcoBus to work at a kiosk in town each morning. "I always see the bus pass by," he says during the journey, "and thought I'd give it a try." It is really great, he goes on to say, that the bus takes him directly to the door for just EUR 2.70.

The little bus wends its way down the steep road into Clausthal. The young man continues: "Back home in Turkey you get little buses like this everywhere. It's pretty funny that they've only just come up with the idea here." However, whilst these buses, known as Dolmus in Turkey, can be flagged down anywhere, they only follow fixed routes and cannot be ordered in ad-

vance, unlike the EcoBus. Anyway, the kiosk owner only spends a few minutes on board until the bus comes to a stop right in front of his kiosk in the town below. As he gets off, he bids the driver, Torsten Keck, a cheery "have a nice day."

THE BUS TRAVELS TO WHEREVER IT IS NEEDED

Torsten Keck continues through the streets, with their pretty half-timbered houses, to his next stop. He has no fixed timetable and glances at the tablet mounted in a holder to the right of the gear lever to see where his next pick-up point is. "Ah, okay," he says, "the next passenger is getting on just behind the market church."

Every few minutes the tablet emits a quiet "ping" whenever a new customer sends a request to be picked up anywhere between Clausthal, Goslar and Osterode. The pick-up requests are

sent to the driver's tablet from a central server via the cell-phone network. "This is the list of the next few stops," he says, tapping the screen. "The system inserts the new customers somewhere along the route I'll be taking in the next few minutes."

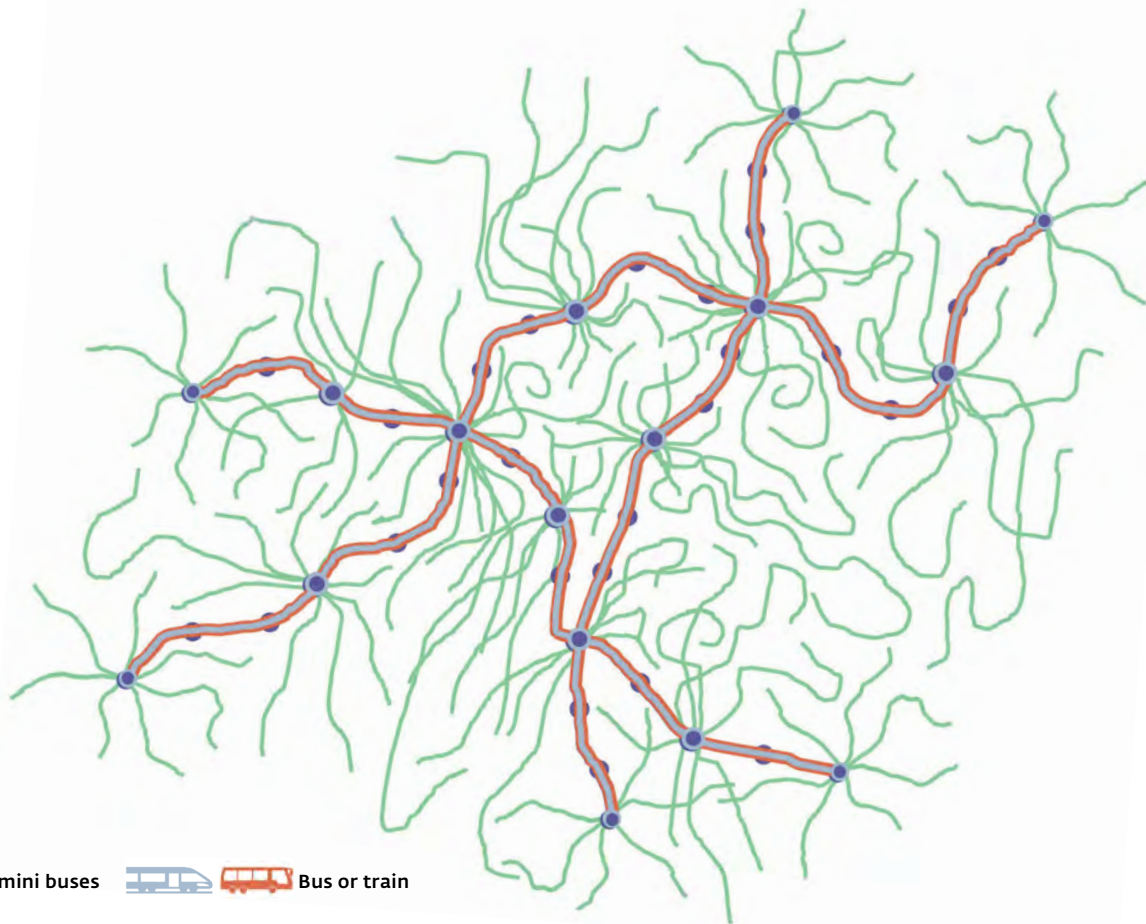
The EcoBuses have been operating in the Harz region since the middle of August. There are currently eight of them, each with eight passenger seats. Some of them even have space for wheelchairs. "We've already got a few regulars, mostly elderly folks." Says Torsten: "A lot of younger people use the service on Fridays and Saturdays." The buses stay out till two in the morning on those nights. He once had a group of young men who brought all sorts of barbecue equipment and provisions on board. He drove them to a barbecue cabin in the country. By the end of 2018, the EcoBus had some 6500 registered users – more than ten per cent of the population within the pilot area. Cus-



"You are the bus stop!" True to this slogan, the EcoBus picks passengers up wherever they like – even at some points along a country road.

tomers can to book the service by phone or using a smartphone app via the website www.ecobus.jetzt (in German). The EcoBus is still just a pilot project launched by researchers at the Max Planck Institute for Dynamics and Self-Organization. The buses are operated by project partners Regionalbus Braunschweig (a subsidiary of Deutsche Bahn), the Zweckverband Verkehrsverbund Süd-Niedersachsen (Administrative Union for the Integrated Transport System of Southern Lower Saxony) and the Regionalverband Grossraum Braunschweig (Greater Braunschweig Regional Association), who have also employed the drivers.

The buses' sliding side doors bear the witty slogan: "You are the bus stop!" which neatly sums up the concept: rather than walking to a traditional bus stop to wait for a service bus, you call the bus to where it is needed. And because most modern smartphones are equipped with a GPS function, the bus can even



be called to remote places such as hikers' car parks, tourist cafés or, for that matter, barbecue cabins far off the beaten track.

"Ultimately," says Stephan Herminghaus, physicist and Director at the Max Planck Institute for Dynamics and Self-Organization, "we want the EcoBus to contribute towards the reduction of private cars on the road by enabling several people to share their journeys." The EcoBus project was his idea. "The basic concept is that passengers board the bus along its route. But, unlike with car sharing, it is the ride that is being shared, not the car. We call it ride sharing."

Of course, as Herminghaus admits, the concept of ride sharing is nothing new. On-demand bus services that operate on a similar principle, picking up passengers along the way, have been around for a considerable time, he says. And, he continues, with modern transport services, such as Uber or Volkswagen's Moia, vehicles can be booked by smartphone at any time and any place.

"The problem," says Herminghaus, "is that all of these services put more ve-

hicles on the roads, which, ultimately, does nothing to reduce road traffic." On the contrary: "Services such as these take passengers from the environmentally-friendly public transport systems and distribute them among many cars." Stephan Herminghaus is familiar with the extreme side effects that can result from this from his own experiences in the Indian metropolis, Bangalore, where for some time now a significant part of the road traffic load has been due to empty trips by cars driving for Uber or Ola, its Indian counterpart. "These are mostly drivers on their way to their next customers, but that is precisely what the future should not look like."

LOCAL TRAFFIC IS INCREASING

The EcoBus is designed to achieve the opposite by getting people out of their cars and onto the public transport services. Its buses have often been an unattractive option to date, as some villages are not even connected to the public service routes or else the buses

are very infrequent. As a result, many people prefer the car, so many large intercity buses currently only carry a handful of passengers. They are referred to in the sector as "ghost buses" and tend to cost the public transport companies money to operate. "The EcoBus that I book to come to a particular spot at a time of my choosing will be able to fill this gap in future," says Herminghaus. "Last but not least, it also provides a shuttle service to the established public transport network – to the train station or the nearest bus stop. This strengthens public transport rather than weakening it." That is why the EcoBus is also being supported by public transport companies themselves in Southern Lower Saxony. It augments the existing network.

At first glance, the EcoBus project has very little to do with the research carried out at the Goettingen-based Institute, where scientists conduct research into flows, self-organizing networks of living cells and dynamic networks such as the electrical grid of the future.

Left-hand page In the traffic concept represented by the EcoBus, such flexible shuttle buses transport passengers to boarding points for regular bus or train services.

This page Stephan Herminghaus and the concept of ride sharing: rather than sharing cars as in the car sharing concept, people share journeys.



“Yet, in the final analysis,” says Stephan Herminghaus, “road traffic is also a flow – a special kind of flow,” whereas that is not the case with traffic. It is true, he says, that in this case too there is a certain flow in a particular direction, but, of course, vehicles can diverge from this main direction. “In this context we talk in terms of active fluids in which particles have proper motion,” Herminghaus explains. “It’s like with plankton organisms. Whilst they are transported in a certain direction by powerful water currents, they can use a rowing motion to change direction.” Thus, the complex phenomenon of road traffic is nothing new to flow researcher Herminghaus.

The idea for the EcoBus project occurred to him several years ago at a time when he had to cross the Reinhaeuser Landstrasse, one of the large multilane arterial roads out of Goettingen, whilst cycling to the Institute each day. “Sitting in almost every car there during rush hour is a single person. I asked myself how we could change that; how

people could be coaxed out of their cars and onto the buses and trains.” The EcoBus is his answer: pick people up in places where there had previously been hardly any alternative to the car.

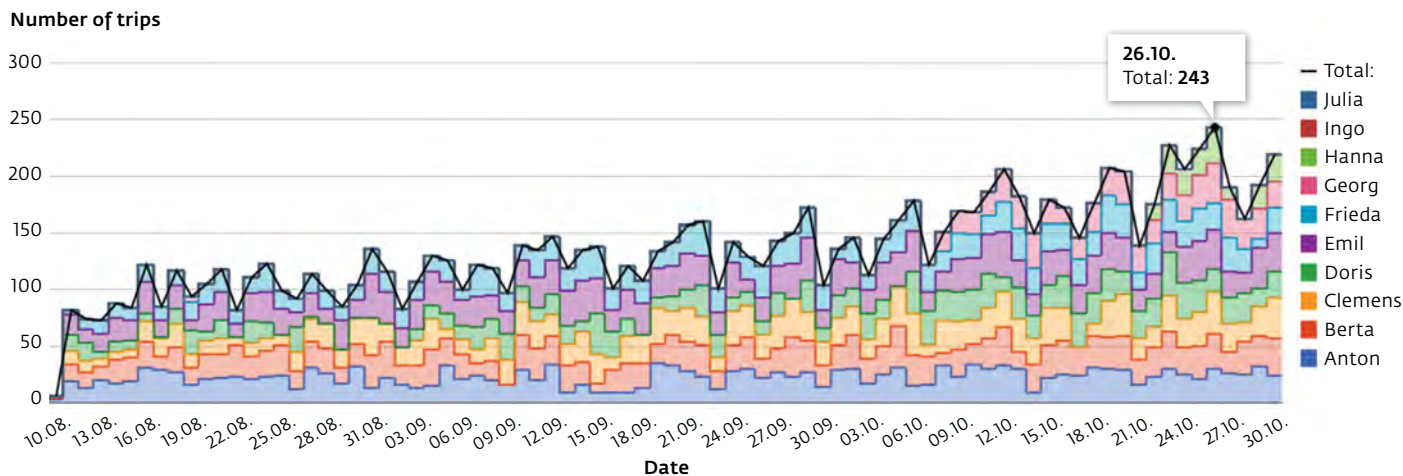
EIGHT BUSES WITH THE TRAVELING SALESMAN PROBLEM

The technology behind this service is so complex that Herminghaus had to assemble a dedicated team of engineers and physicists. This is because to send an EcoBus out on its rounds means mastering several challenges. For example, the EcoBus concept relates to a classic mathematical problem. Called the “traveling salesman problem” it has been known since the 1930s and involves finding the shortest route between several towns that a traveling salesman wants to visit. Yet, the more towns there are, the greater the number of alternative routes: the 15 biggest cities in Germany, for example, can be connected via 43 billion different route combinations! There are now a pletho-

ra of algorithms that produce solutions to this optimization task. They are used in Satnav systems among other things.

“But our work goes quite a bit further than this routing problem” says Tariq Baig-Meininghaus, who worked intensively on a route finding solution within the EcoBus project. “We’re not dealing with a traveling salesman, but with many passengers who want to be picked up and dropped off again. In addition to that, at present, we need to coordinate the routes of eight buses.” For example, a bus that is currently traveling in the direction of Clausthal-Zellerfeld should not pick up passengers whose destination is Goslar in the opposite direction – and vice versa. And another thing: the routes change continuously because new guests are always submitting their shuttle requests.

It took Tariq Baig-Meininghaus and his colleagues a good two years to reconcile all of these requirements, and, although there are already various software solutions on the market, a lot



Increasingly popular: of the ten buses with names such as Julia, Frieda and Anton, up to eight are in operation every day, whereby the number of trips has increased since the start of the pilot project.

of manual work was still needed. So whilst many research groups have published routing algorithms in the past, the majority of them are too slow for the EcoBus. “If a customer requests a bus then they want to know within seconds when one will be free and when it will arrive,” says Baig-Mein- inghaus. “An offer has to be made within twelve to 15 seconds or the system would feel too slow.”

He and his colleagues solved the problem in such a way that the EcoBus system really does provide an initial response to the customer request within a few seconds whilst the algorithms continue to work in the background to optimize the route and coordinate the many customer requests, which takes them a bit longer. The customer has no inkling of this. The researchers also made the system faster by dividing the entire EcoBus region into sub- units, for which detailed calculations

are first performed. Finally, the software synchronizes the individual areas and interim results to produce an overall solution.

FURTHER STEPS TOWARDS A RELIABLE TIME OF ARRIVAL

Coordinating all buses and customers or timing – there were many parameters that the researchers had to tweak for their EcoBus system. In particular, this also includes placing customer requests in a practical sequence to avoid the excessive prolongation of individual passengers’ journey times. Bus driver Torsten Keck knows why: “I recently had a passenger who spent almost an hour in the bus because other passengers, whose pick-up points were along the route, had booked the service. The trip then got longer and longer due to the short detours – and at some point the passenger let it be known that he’d like to get home in the not too distant future.”

The experts did program a maximum journey time per passenger into their system, but, because there are currently only eight buses in operation in

the pilot project, a trip can simply take up to an hour on occasion. In other cases, the customers still have to wait quite a long time till the next free bus comes their way. “I once had to wait an hour and a half for the bus,” says the young kiosk owner from Clausthal. But the more buses in operation in future, the faster the service should be.

The EcoBus is therefore by no means a hundred per cent plannable for the customers at this time, not least because the buses do not always arrive at their destinations to the exact minute. For project leader Stephan Herminghaus, that is the next step. He wants to further develop the system over the coming months so that it can give the passengers a reliable time of arrival – for example to get them to the station in Goslar on time for them to catch their connecting train.

But, even then, a precise departure time from the front door will not be possible. “Such complete flexibility will not be achievable with ten buses – the area between the three towns with its 63,000 residents is simply too big,” says Herminghaus. “So, the way it’ll work initially is that we’ll be able to give the

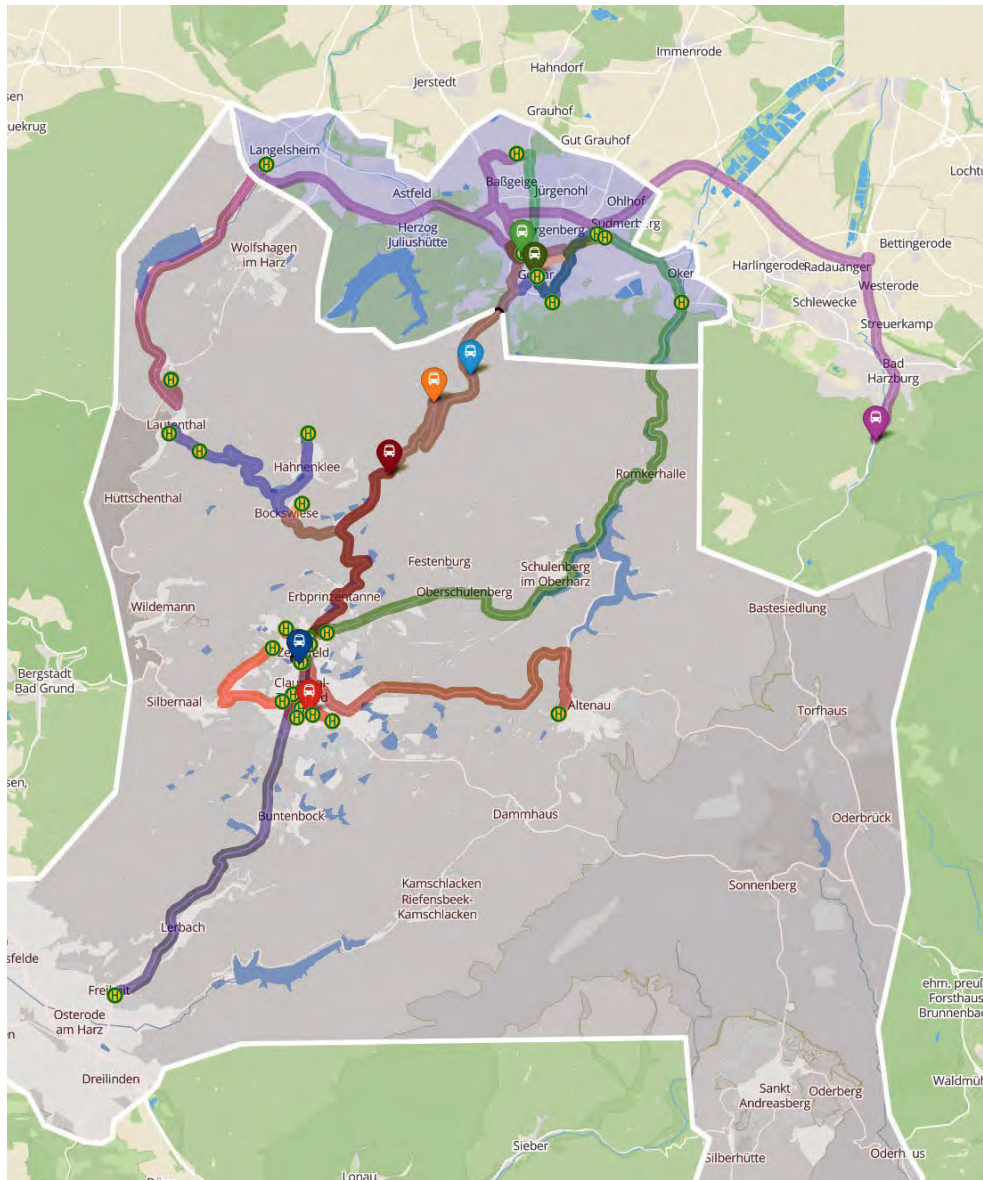
Flexible routes: the EcoBus also operates in rural districts in which there are no public transport services. The map shows an example of the routes traveled by the various mini buses on a particular day. During these trips, they stopped to pick up passengers at all the points marked by the bus stop symbol.

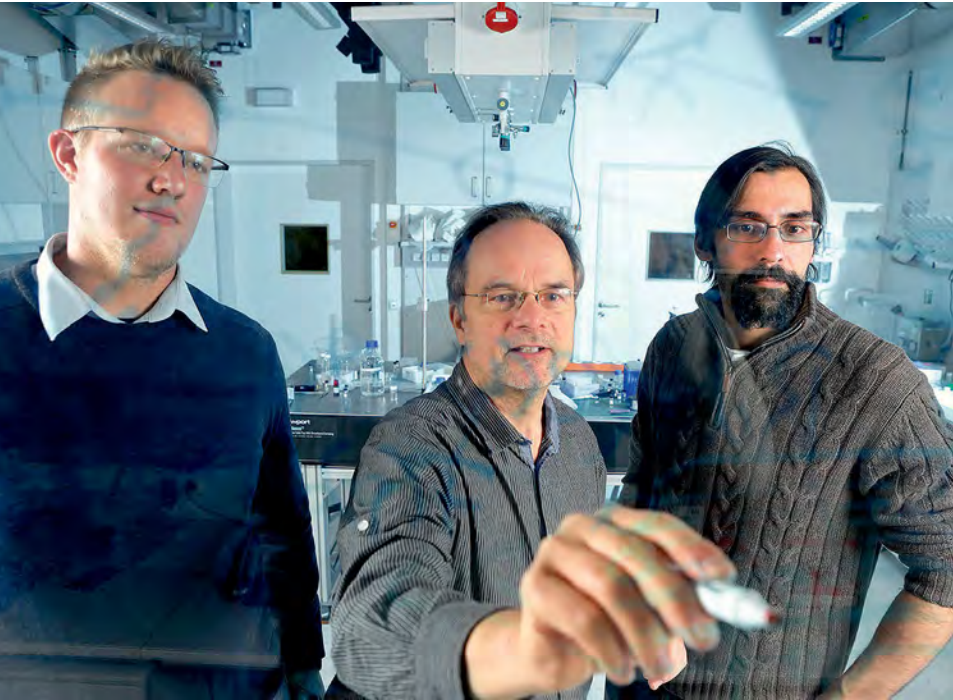


passenger an accurate time of arrival and a period during which we'll pick them up – that's achievable." Alternatively, a cooperation agreement with taxi firms would be feasible. Customers in a rush could be collected by taxi and transferred to an EcoBus somewhere along the way that would take them the rest of the way to the train station.

SIMPLIFYING THE SYSTEM WITH PUBLIC PARTICIPATION

However, the EcoBus project involves more than just the software that works in the background to synchronize all bus movements and customer requests; it also includes the visible elements. "We developed everything ourselves," says electrical engineer Christoph Brügge, "The app and the website through which you can book a trip as well as the Satnav system used by the bus drivers." To this end, Brügge and his colleagues also organized public events during which they asked locals about their expectations of such a system. "We wanted to keep the system as simple as possible so that older people, in particular, would be able to use it."





Tailor-made mobility: Christoph Brügge, Stephan Herminghaus and Tariq Baig-Meininghaus (from left) are members of the team that developed and continue to improve the EcoBus. A next step is to be able to provide passengers with reliable arrival times.

Because the buses are operated by the public transport companies themselves, the tariffs are easy to understand – and the tickets can be transferred. The fares are the same as for the public service buses: a trip through Goslar costs the usual EUR 2.70 and the route from Clausthal to Goslar costs EUR 4.00. Among other things, passengers can also purchase a Deutsche Bahn Niedersachsensenticket (Lower Saxony Ticket) to enable them to use public transport throughout the state. “We initially found integrating the public transport ticket printers within our system to be an additional level of complexity,” says Stephan Herminghaus. “However, we’ve come to realize that this is an additional benefit to our customers because it integrates the bus directly into the transport associations’ tariff systems.”

Herminghaus emphasizes the fact that he is not trying to reinvent the wheel with the EcoBus: “I’m pretty certain that companies such as Uber use very similar algorithms – all developers use similar tools, after all,” says the researcher. “But, unfortunately, private companies keep their cards close to their chests so that, in the end, we did have to set up a system of our own after all.”

OTHER TOWNS AND CITIES ARE ENQUIRING ABOUT THE ECOBUS

This is a system with evident appeal, as the public transport companies are very interested. One member of the team is currently developing an EcoBus solution for the Leipzig transport services, with which the goal of precise passen-

ger arrival times should shortly be realized. Initially, two EcoBuses will be deployed in Leipzig for this purpose. The test is intended to demonstrate that the bus can interact perfectly with the regular bus and train timetables.

“Other municipalities have enquired about when we’ll finally be launching the EcoBus as a product and service on the market,” says Herminghaus. In the meantime, he continues, he has already developed an appropriate business model in conjunction with his colleagues from Max Planck Innovation, the Max Planck Society’s central technology transfer hub. “The concept is attractive because we would bear the risk. Our goal is to operate the call system as a service at our own cost and to fund it via small fees to be paid with each booking,” the researcher explains. But he is not yet able to say precisely when the EcoBus service will be on sale.

However, the pilot project in the Harz region has already demonstrated that the service works, and the researchers learned a lot from it: “Especially that interacting with the real world sometimes looks very different to the way a physicist imagines it will in theory,” says Tariq Baig-Meininghaus with a smile. “The passenger can certainly point the cursor at the exact spot on the map in the app where they want to be picked up – but, it’s still sometimes hard for drivers to find people, which can delay the departure time – you need to take account of this kind of thing in the system.” And the researchers encountered another stumbling block during the pilot project in the Harz region: dead zones!

On the route from Goslar to Clausthal-Zellerfeld Torsten Keck steers his bus through tight bends and serpentine. The bus dives down into a thickly forested river valley – no chance of cell phone reception. The tablet only comes back to life as the bus drives into Goslar: Ping! Ping! Ping! Ping! “We’re

back online,” says Torsten. “Now all the new customer requests will come rolling in.” And suddenly his route plan looks completely different. The EcoBus server has already arranged the requests in the correct sequence. “That’s the nice thing about this job: you’re always driving different routes. And, I’ve already discovered a few little places that I hadn’t even known existed before.” There is no doubt the EcoBus is opening up new prospects, not just for drivers like Torsten Keck, but especially for the customers and rural districts such as the Harz region, in which people still find themselves sitting in ghost buses much too often. ◀

SUMMARY

- Rural bus services are rare if they exist at all. Because many people prefer to use their cars all the time, those buses that are in service are extremely underutilized.
- That is why researchers at the Max Planck Institute for Dynamics and Self-Organization developed the EcoBus to make public transport more flexible, whereby, among other things, they had to solve an especially difficult route finding problem. Public transport companies in Lower Saxony are currently testing the system between Goslar, Clausthal-Zellerfeld and Osterode am Harz.
- The EcoBus picks people up where they want to get on and takes them right to where they want to go. Although the system is not yet able to specify precise departure and arrival times, because the route is changes continuously in response to new requests, it should soon be able to provide reliable arrival times – not least to enable customers to catch their connecting buses and trains on time.
- By contrast with other on-demand bus service systems, the point of the EcoBus is to reduce the number of vehicles on the roads, because as part of the public transport services, it augments service buses and trains.

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The Foundation funded a 130-meter Helium balloon for the Max Planck Institute for Solar System Research, enabling one of the world’s largest solar telescopes to get off the ground.

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