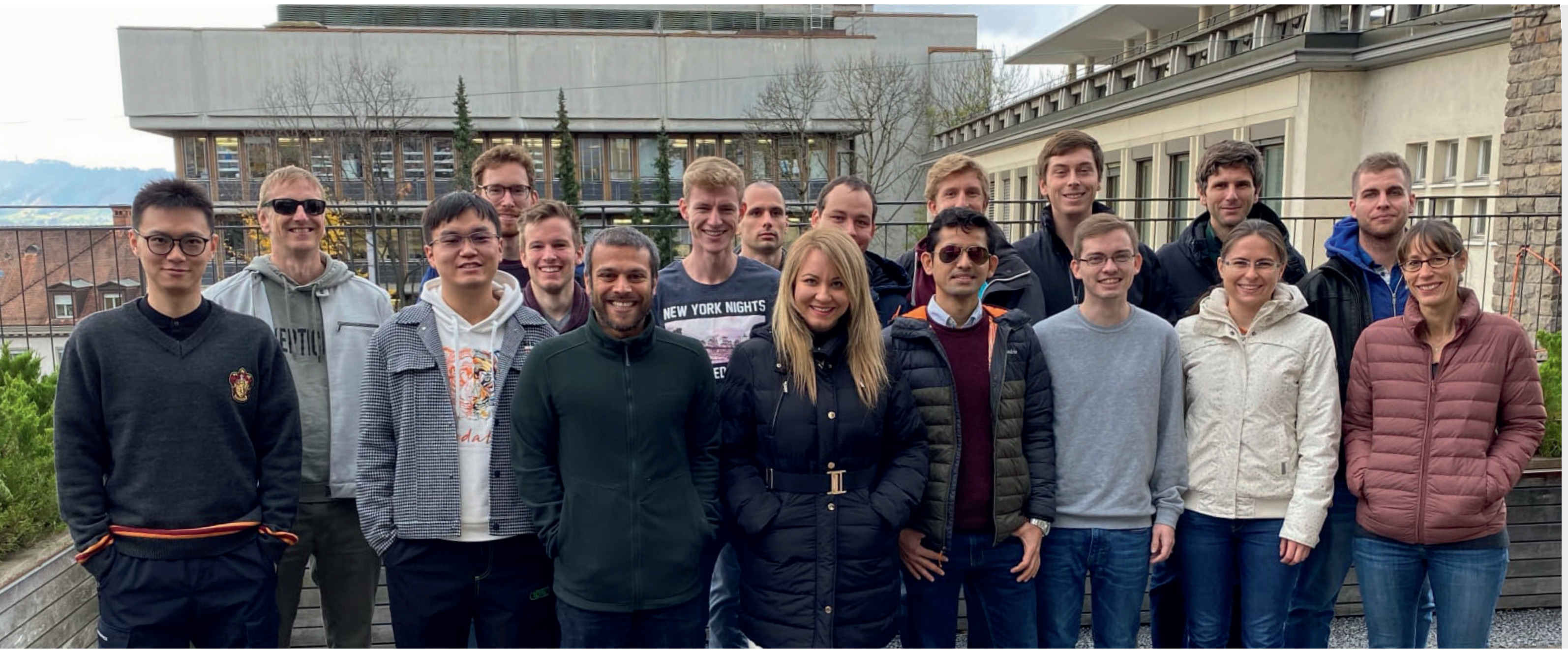
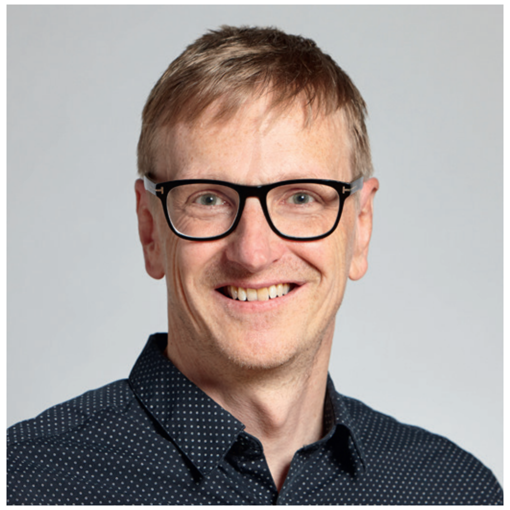
Information and Communication | Distributed Computing Group | Professor Roger Wattenhofer



Distributed Computing Group
Professor Roger Wattenhofer

In our group, we study networks. We currently focus on four areas:

- Distributed systems: fault tolerance, blockchains, cryptocurrencies, digital money
- Theory of networks: financial networks, e-democracy, decentralized finance, online analysis with delay, theory of distributed algorithms
- Machine learning: reinforcement learning, deep neural networks, natural language processing, graph neural networks, algorithmic learning
- Embedded systems: signal processing, location systems



Prof. Roger Wattenhofer

Curriculum vitae

2008 – today	Full Professor, D-ITET, ETH Zurich
2004 – 2008	Associate Professor, D-ITET, ETH Zurich
2001 – 2004	Assistant Professor, D-INFK, ETH Zurich
2000 – 2001	Postdoc Researcher, Microsoft Research, Redmond, WA
1999 – 2000	Postdoc Researcher, Brown University, Providence, RI
1995 – 1999	PhD in Computer Science, ETH Zurich

Top picture: Distributed Computing Group

Goals and priorities

We generally strive to work on exciting new research questions in upcoming new areas. We believe that the best research happens at the boundary of or between established areas. While we originally only considered computer networks and networks of embedded systems, more recently we opened up to various other types of networks. We study many questions before they are considered by others. For example, we were the first to introduce the concept of off-chain networks for blockchains, which is now the main research area in the blockchain community.

Regarding education, our philosophy is to have as much interactions with the students as possible. Before Covid-19, a typical lecture would start by the professor asking a short question of the form: How would you solve this problem? Then students would come up with suggestions and discuss why these suggestions might be flawed. As a group we would then gravitate towards learning fundamental concepts that solve the problem (and other related questions) nicely. While Covid happened, we experimented with mini-quizzes instead.

Knowledge transfer plays a minor role in the group, but there are exceptions. For instance, our eFranc proposal for a central bank digital currency is currently being evaluated and discussed at the Swiss National Bank.

Research impact

Our research impact is predominantly of academic nature. We publish at top venues, and our work is well cited. It is not uncommon for our PhD students to have already more than 100 citations when they graduate. Our work on wireless protocols has inspired so much follow-up work that the yearly Workshop on Realistic Models for Algorithms in Wireless Networks has been initiated by colleagues in the community.

We also work in areas which have societal impact. For instance, we work on e-voting, and we generally study how we could strengthen our democracy through technology. About twice per year, Prof. Roger Wattenhofer writes an article to be published on the main website of ETH Zurich. These articles have been reprinted or adopted by newspapers and magazines.

Teaching activities

The teaching in our group is done exclusively by Prof. Roger Wattenhofer, with exercise sessions organized by the PhD students. In the last five years, we developed two new courses: First, a course on operating systems and networks. Furthermore, a course on computational thinking, which combines the fundamental areas in computation: algorithms, complexity, cryptography, data and storage, machine learning, neural networks, and computability. We also completely redesigned our distributed systems course. Apart from these Bachelor's level courses, we continued teaching our Master's level course on distributed computing. We also organize seminars, recently in the area of deep neural networks, and various hands-on labs for students. In total we teach about 800 students and supervise 50 to 70 student theses every year.

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Research activities and achievements

Instead of summarizing all our research, we will simply highlight some of our current work.

Financial networks

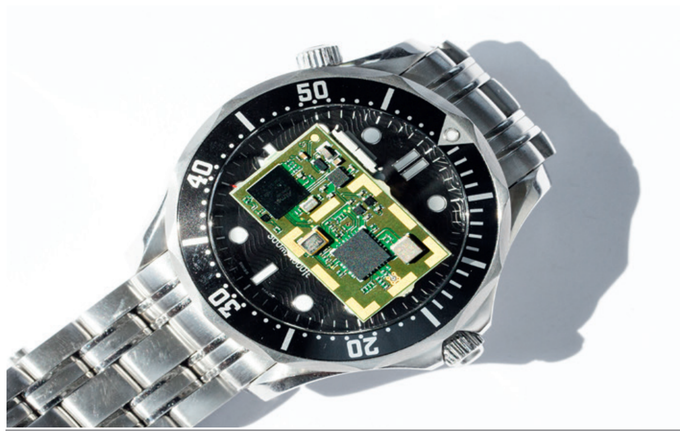
Banks and other financial institutions are interconnected by various kinds of contracts. Any financial crisis is by definition a crisis of many banks, so it is crucial to analyze financial systems from a networking perspective. In such a setting, many fundamental problems turn out to be computationally difficult: e.g. how can we save a large number of banks from bankruptcy with only limited resources? Surprisingly, sometimes one cannot even decide whether a bank is bankrupt or not! If we also study the incentives and actions of banks in these networks, e.g. whether they are motivated to donate funds to other banks or exchange some contracts with each other, then these networks are capable of producing interesting game-theoretic situations.

Online algorithms with delay

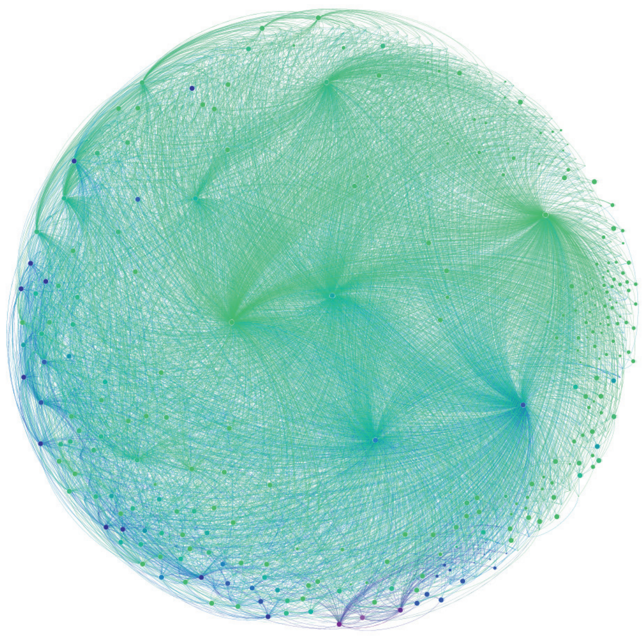
In many situations the input of an algorithm is not known at the beginning but appears over time. For example, on an online chess platform, players join the system at arbitrary times. Players want to be matched to an opponent with similar skills, and they do not want to wait long before a match starts. We solve this problem with a quality guarantee, maximizing matching quality and minimizing waiting times. This setting is interesting in many application areas, e.g. assigning taxis to customers, or matching organ donor-receiver pairs. We started this area of research, and have come up with multiple upper and lower bounds on the competitive ratios of algorithms in this framework.

Understanding transformers

Neural networks have emerged as a powerful tool for pattern recognition. In recent years, the design of network architectures was inspired by simulating human attention. This analogy led to many interpretations of what these algorithms might have learned based on what the network "attends" to. We show that these interpretations are only partially justified, as deep networks with multiple layers already attend over mixtures after the first layer. Moreover, in the popular transformer architecture, attention weights can be modified without changing the function represented by the network. This means that a completely different interpretation might be given for the same function! Luckily, the training procedure gives attention weights that correlate with the function of their corresponding layer, giving some credibility to certain interpretations. However, to which extent any object-centric view can quantify the intricate inner workings of neural networks is still an interesting open question.



Multi-year GPS tracking with a watch for size comparison.
A student manually did the amazing soldering work
(metric SMD 0.4 mm x 0.2 mm).


Our *light* visualization of the link structure of the dark web

Graph neural networks

Some of the world's most interesting data is represented by graphs, but classic neural networks cannot handle such non-tabular input. We are developing a new approach called DropGNN which dramatically increases the expressiveness of neural networks dealing with graphs. The main idea is to execute not one but multiple different runs when testing an input graph. We then aggregate the results from these different runs into a final result. In each run, we remove each node in the graph with a small probability. As such, the different runs allow us to observe slightly perturbed versions of the neighbourhood.

Blockchain scalability

Blockchains are revolutionizing the digital payment (and trust) systems, but their widespread adoption is limited by the low transaction throughput. We propose to optimize solutions for fast payments in blockchain protocols, either by introducing novel protocols that scale to thousands of participants, or by exploring off-chain payment solutions that allow blockchains to scale arbitrarily. Off-chain payments face major security challenges related to timing and participation assumptions, monetary incentives and high capital demand. We successfully addressed most of these challenges, introducing state-of-the-art off-chain payment protocols like Brick leading the way to more efficient blockchain systems.

Consensus

Consensus protocols make sure that participants in a distributed system are able to agree on a common value, for example a reasonable sensor measurement. When building robust systems, we assume that some participants may crash or even show malicious behaviour. Such behaviour should not prevent a protocol from establishing agreement. The challenge is to design a system that can tolerate as many failures as possible while providing an "accurate" value as consensus output. We are looking into different scenarios, for instance participants that need to agree on real-valued data (for sensors) or a common ranking (for distributed machine learning).

Localization

Determining the exact location of a user is important for many mobile services. We work on improving the performance and power efficiency of GPS algorithms and also develop alternative localization methods based on already existing signals, such as transmissions by aircraft for air traffic surveillance. With the advent of affordable SDRs, security aspects of radio transmissions such as GPS signals become important. An attacker can try to manipulate these important systems. Therefore, we develop techniques to detect such attacks.

10 Key publications

1 Zeta Avarikioti, Eleftherios Kokoris-Kogias, Roger Wattenhofer and Dionysis Zindros. Brick: Asynchronous Incentive-Compatible Payment Channel. Financial Cryptography and Data Security (FC), Online, March 2021.

2 Pál András Papp and Roger Wattenhofer. Sequential Defaulting in Financial Networks. 12th Innovations in Theoretical Computer Science (ITCS), Online, January 2021.

3 Gino Brunner, Yang Liu, Damian Pascual, Oliver Richter, Massimiliano Ciaramita and Roger Wattenhofer. On Identifiability in Transformers. 8th International Conference on Learning Representations (ICLR), Online, April 2020.

4 Manuel Eichelberger, Ferdinand von Hagen and Roger Wattenhofer. A Spoof-Proof GPS Receiver. 19th ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN), Sydney, Australia, April 2020.

5 Rui Ray Zhang, Xingwu Liu, Yuyi Wang and Liwei Wang. McDiarmid-Type Inequalities for Graph-Dependent Variables and Stability Bounds. Spotlight Paper. 33rd Conference on Neural Information Processing Systems (NeurIPS), Vancouver, Canada, December 2019.

6 Manuel Eichelberger, Simon Tanner, Gabriel Voirol and Roger Wattenhofer. Imperceptible Audio Communication. 44th IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Brighton, United Kingdom, May 2019.

7 Darya Melnyk, Yuyi Wang and Roger Wattenhofer. Byzantine Preferential Voting. 14th Conference on Web and Internet Economics (WINE), Oxford, United Kingdom, December 2018.

8 Manuel Eichelberger, Kevin Luchsinger, Simon Tanner and Roger Wattenhofer. Indoor Localization with Aircraft Signals. 15th ACM Conference on Embedded Networked Sensor Systems (SenSys), Delft, The Netherlands, November 2017.

9 Magnús M. Halldórsson, Stephan Holzer, Pradipta Mitra and Roger Wattenhofer. The Power of Oblivious Wireless Power. SIAM Journal on Computing, July 2017.

10 Yuval Emek, Shay Kutten and Roger Wattenhofer. Online Matching: Haste Makes Waste! 48th Annual Symposium on the Theory of Computing (STOC), Cambridge, Massachusetts, USA, June 2017.

All publications can be found on the *Distributed Computing Group's* website: www.disco.ethz.ch.
For further information, please consult Prof. Wattenhofer's *Google Scholar* page:
https://scholar.google.com/citations?user=EG3VPm4AAAAJ