NETWORKS

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THENETWORKCENTER.NL

ANNUAL REPORT 2018

2018 has been quite a remarkable year for NETWORKS, with great scientific progress and many highlights. In this fifth year of the funding period, the program continues to be in full swing.

After last year's midterm review, it was the right moment to rethink the program's orientation and objectives. An important input here was the self-evaluation document that we wrote in preparation of the midterm, as well as the report written by a committee of 'Critical Friends' discussing the progress of the program as a whole, with a focus on scientific and strategic aspects. To obtain concrete operational input on the program's direction for the period 2018-2024, we met in February with our Scientific Advisory Board. They provided us with very thoughtful and constructive advices, not just on purely scientific aspects but also on issues such as valorization, interdisciplinarity, outreach, and gender policy.

Looking at the NETWORKS team, 2018 marked the first PhD defenses of many more to come over the next years. Remarkably, the first two PhD students to graduate, Souvik Dhara and Debankur Mukherjee, both obtained their degree with distinction. Lex Schrijver (UvA and CWI) will retire in 2019 and, as a result, step down as PI and management team member. We are happy to announce that Leen Stougie (CWI) has agreed to succeed him. We also welcome Frits Spieksma (TU/e), who succeeds Gerhard Woeginger (TU/e) as a PI; this position was temporarily taken over by Nikhil Bansal (CWI and TU/e). In 2019 and 2020, a second batch of PhD students will gradually start.

In 2018, much emphasis has been put on outreach activities. In April, we organized a two-day masterclass event on networks and their applications at Leiden University and the University of Amsterdam. Aimed at secondary education students and teachers, the program consisted of lectures by NETWORKS members, discussions, games, reading sessions, and interactive group activities. In addition, under the umbrella of KNAW, we organized in November a thematic evening for a broad audience at the public library in Amsterdam. Engaging talks were given by Jacobien Carstens (UvA), Stella Kapodistria (TU/e), Monique Laurent (CWI), and Nelly Litvak (TU/e).

Scientifically, 2018 was again a year with an impressive scientific output, resulting in publications in leading journals and presentations at major conferences on probability, combinatorics, operations research, and algorithms. The interactions between the different research groups within NETWORKS have reached a mature level.
For the Training Weeks, we shifted focus from mini courses to the dissemination of results within the program, and to searching new opportunities for collaboration.

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Much attention has been paid to intensifying the interactions with partners from outside the consortium. A second joint doctorate between NETWORKS (UvA) and the ARC Centre of Excellence for Mathematical and Statistical Frontiers (University of Queensland, Australia) has been realized. In addition, in January, there was a joint workshop in Kolkata (India), co-organized with our colleagues at the Indian Statistical Institute (ISI). A second workshop was held in Leiden in June. A joint PhD student (appointed at TNO and UvA) started in February, working in the field of road traffic networks. Possible collaboration with ING and ABN AMRO is currently being explored, aiming at applying network-theoretic techniques to describe banking networks, and to understand the underlying dynamics.

We hope you will enjoy reading this annual report, which provides an overview of the NETWORKS activities in 2018. Additional information can be found on our website (www.thenetworkcenter.nl) and on the Network Pages.

Michel Mandjes (Project Leader)
Marieke Kranenburg (Project Manager)

'NETWORKS goes to school', Amsterdam

RESEARCH THEMES

NETWORKS follows an integrated approach combining stochastic modeling (essential to capture the uncertainty and variability of networks) and algorithmics (needed to control and optimize networks). The overarching research objectives of the program are to gain a better understanding of the relevant structural properties ('Network Structure') and to use these insights in the control and optimization of complex networks ('Network Shaping'). To structure these objectives, we defined seven research themes. These research themes are not independent: many of the ongoing projects relate to multiple themes. The research themes act as different lenses through which we can view our networks of interest. They help us to distribute our research efforts in a balanced way over the various questions arising from these networks. Below, we give the highlights of each research theme.

THEME 1: APPROXIMATE AND EXACT NETWORK METHODS

The design, optimization, and control of networks lead to a large variety of challenging algorithmic problems. Unfortunately, many of these problems are NP-hard, which means that there are no efficient algorithms that solve these problems optimally on all possible instances. Nevertheless, NP-hard network problems need to be dealt with in practice. One approach to is to develop approximation algorithms, which are guaranteed to compute solutions that are close to an optimal solution. Another approach is to exploit the fact that not all input instances are equally hard: some instances enjoy structural properties that make it possible to compute an optimal solution in an efficient manner. In Theme 1 we explore these and other approaches to algorithmic network problems.

HIGHLIGHTS

- Sensor networks are often modeled as so-called unit-disk graphs: graphs whose nodes correspond to disks of radius 1 in the plane, with an edge between two nodes when the corresponding disks intersect each other. Many classic graph problems can be solved in $2^{O(\sqrt{n})}$ time on unit-disk graphs, while for general graphs these problems seem to require $2^{\Omega(n)}$ time. However, existing results on unit-disk graphs use ad-hoc methods and extensions to higher-dimensional intersection graphs are often missing. Mark de Berg (TU/e), Hans Bodlaender (TU/e and UU), Sándor Kisfaludi-Bak (TU/e), Dániel Marx (Budapest), and Tom van der Zanden (UU) presented a general framework to obtain algorithms with $2^{O(n^{1-1/d})}$ running time for any type of disk-like objects in *d*-dimensional space. They also proved that the resulting algorithms are optimal, assuming the exponential-time hypothesis.

- The graph-coloring problem is one of the oldest problems in graph theory. It can be used to model a wide variety of scheduling problems and has therefore received a lot of attention. The objective is simple —assign a color to each node of a given graph so that nodes that are connected by an edge get different colors—but finding a coloring that uses as few colors as possible is NP-hard. Bart Jansen and Jesper Nederlof (TU/e) developed novel algorithms to solve the graph-coloring problem in polynomial time when the graph has certain structural properties, namely small cutwidth or small pathwidth. By clever use of linear algebra, they obtain coloring algorithms that are exponentially faster than earlier algorithms based on small vertex separators.

- The maximum independent set is another fundamental graph problem with many applications. The important special case of bounded-degree graphs has been studied widely, but the question as to the best possible approximation ratio was still open. Nikhil Bansal (TU/e), Anupam Gupta and Guru Guruganesh (Carnegie Mellon) almost settle this by giving an algorithm whose approximation ratio is very close to $O(d/\log^2 d)$, which is best possible under the unique games conjecture. A key ingredient is a new Ramsey theoretic bound for independent sets in bounded degree graphs with no *r*-cliques.

THEME 2: SPATIAL NETWORKS

In many applications the networks under consideration are embedded in space, leading to geometric networks. Examples are railway networks, where nodes correspond to stations and edges to railway tracks, and large molecules, where nodes correspond to atoms and edges to chemical bonds. In many real-world networks the geometry is an important feature that is hard to treat mathematically. Typically, connections between nearby nodes are more abundant than connections between distant nodes, yet long-range connections play a crucial role in the small-world behavior these networks exhibit, i.e., all vertices are connected via short connecting chains. In addition, a high variability in the degrees of the nodes is observed. A key spatial stochastic model is percolation, while a well-known algorithmic problem where geometry plays a key role is the Euclidean traveling salesman problem.

HIGHLIGHTS

- The traveling salesman problem (TSP) concerns computing the shortest round trip through a given set of n cities. It is one of the most famous problems in all of computer science, and of great practical as well as theoretical importance. One of the most widely studied TSP variants is the Euclidean TSP, where the locations to be visited are modeled as points in a two or higher-dimensional space. Despite its prominence—the discovery of a polynomial time approximation scheme (PTAS) for Euclidean TSP won Arora and Mitchell the Gödel prize in 2010—the exact complexity of Euclidean TSP was still not settled. Mark de Berg (TU/e), Hans Bodlaender (TU/e and UU), Sándor Kisfaludi-Bak (TU/e), and Sudeshna Kolay (TU/e) showed that Euclidean TSP in R can be solved exactly in $2^{O(\mathrm{n}^{1-1/d})}$ time, and that this is optimal under the exponential time hypothesis (FOCS 2018).

- Margriet Oomen (UL), jointly with Andreas Greven (Erlangen) and Frank den Hollander (UL), is working on spatial populations with seed-bank. Individuals live in colonies and are subject to resampling and migration as long as they are active. Each colony has a seed-bank into which individuals can retreat to become dormant, suspending their resampling and migration until they become active again. The goal of the project is to classify the long-time behavior of the population in terms of the underlying model parameters; in particular, to understand how the presence of the seed-bank affects this behavior. One result is that the population exhibits a dichotomy of coexistence (= multi-type equilibrium) versus clustering (= mono-type equilibrium). Another result concerns the finite-systems scheme, which captures how the scaling of a finite truncation of the population behaves as both the time and the truncation level tend to infinity, properly tuned together. Both the dichotomy and the scaling in the finite-systems scheme are affected by the seed-bank when the wake-up time has infinite mean, and new universality classes appear.

- Owing to their capability of summarizing interactions between elements of a system, networks have become a common type of data in many fields. Paulo Serra (TU/e) and Michel Mandjes (UvA) have studied inference methods for the local properties of inhomogeneous networks. In the first place, an estimator has been proposed that is based on local weighted averaging. Secondly, a Monte Carlo cross-validation procedure has been set up to pick the parameters of this estimator.

- In collaboration with Castell, Gaudilliere, and Melot (all at CNRS), Luca Avena (UL) developed a randomized renormalization scheme for arbitrary graphs based on spanning random forests and random walk explorations. This renormalization allows to coarse-grain/reduce the adjacency matrix of a big network in a multiscale fashion to obtain smaller networks that are easier to analyze/visualize, and from which information on the spatial geometry of the original big network can be recovered. The related algorithm runs in polynomial time and has good scaling properties. Further, this renormalization scheme forms the basis for a novel wavelets transform to process (i.e. compressing, de-noising) arbitrary signals (real-valued functions) defined on the vertex set of a graph. The resulting algorithm is called “intertwining wavelets” because the underlying main idea is to combine the above-mentioned renormalization together with so-called intertwining, an algebraic duality notion to link different Markov chains.

- Remco van der Hofstad, Tim Hulshof, and Jan Nagel (all TU/e) investigated random walks on barely supercritical branching random walk obtained by performing near-critical percolation on a super-critical branching random walk. They show that the variance of the limiting Brownian motion sensitively depends on how close the model is to criticality, and shows interesting scaling behavior. The proof makes use of a general regeneration time approach, where the estimates are performed uniformly in the percolation parameter. In particular, since critical branching random walk is the mean-field model for critical percolation in high dimensions, the result sheds light on the conjectured scaling of the variance of random walk on barely supercritical high-dimensional percolation clusters.

- Further investigated topics include the study of bond percolation on the d-dimensional Hamming graph (the Cartesian product of d copies of the complete graph) by Lorenzo Federico (TU/e), Remco van der Hofstad (TU/e), Frank den Hollander (UL), and Tim Hulshof (TU/e), and conflict-free colorings arising in frequency-assignment problem in cellular networks by Aleksandar Markovic and Mark de Berg (TU/e).

THEME 3: QUANTUM NETWORKS

Quantum computers are the next generation computing devices. They hold a tremendous promise to revolutionize the way we process and handle information throughout science, technology, and our rapidly evolving information society. Quantum computers can be used to implement quantum algorithms, which in many instances are able to perform computations much faster than classical algorithms.

HIGHLIGHTS

- Theoretical work of Tom Bannink, Harry Buhrman, Jop Briët, Farrokh Labib (all at CWI), and Lee (University of Technology Sydney) on quantum nonlocality will be

implemented in practice in the laboratories of experimental physicists Thomas Monz and Rainer Blatt, both in Innsbruck. A functional small-scale proof of concept has motivated a future larger-scale quantum supremacy experiment. The same group plans to implement quantum random walks on the line and the grid.

- Work of Briët and Sivakanth Gopi (Microsoft) was published in *International Mathematics Research Notices*. In it, they describe their progress on a problem from nonlinear large deviations, related to the count of arithmetic progressions in Bernoulli random sets. This problem is of interest to NETWORKS due to connections with the infamous triangle count problem in Erdos-Renyi random graphs.

- Work of Srinivasan Arunachalam (MIT), Briët, and Carlos Palazuelos (Universidad Complutense Madrid) was presented at the 2018 ITCS conference in Berkeley. This work gives an exact characterization of quantum query algorithms in terms of the unit ball of a space of low-degree polynomials. Relevance to NETWORKS stems from the fact that quantum walk algorithms are special instances of quantum query algorithms.

- Buhrman co-authored *The quantum technologies roadmap: a European community view* (published in New Journal of Physics), which updates an existing 150-page precursor presented to the high-level steering committee in 2016 in preparation for the European Commission Quantum Technologies Flagship initiative.

- A development outside of NETWORKS that is worth mentioning concerns the lively connection of the NETWORKS

NEW PERSONNEL

Dr. Georgios Amanatidis
Postdoc, CWI

Ruben Brokkelkamp, MSc
PhD-student, CWI

Dr. Conrado Da Costa
Postdoc, UL

Tiny Dekker
Support Staff, UvA

Lucas van Kreveld, MSc
PhD-student, UvA

prof. dr. Leen Stougie
PI, CWI

prof. dr. Frits Spieksma
PI, TU/e

quantum group with QuSoft and the Quantum Software Consortium (an NWO Gravitation program running in parallel with NETWORKS). QuSoft has attracted much interest from a number of companies and currently hosts a PhD student and postdoc working on a collaborative project with Bosch. Members of QuSoft have been bridging the gap between the academia and industry by acting as consultants to update companies on the state of the art of quantum computing. Thanks to the Quantum Software Consortium, the group at CWI is expected to grow in the coming period.

THEME 4: DYNAMICS OF NETWORKS

Networks typically evolve over time. The way in which this happens is often closely related to their functionality. Random graphs are essential tools to model real-life network structures as stochastic objects that grow in time according to certain local growth rules. By adapting these rules, different types of dynamic network behavior can be captured and analyzed.

HIGHLIGHTS

- Hakan Guldas, jointly with Luca Avena, Frank den Hollander (all at UL), and Remco van der Hofstad (TU/e), completed two papers analyzing the mixing time of a random walk on a dynamic random graph. The random graph is drawn according to the configuration model and subsequently evolves through rewiring of a fraction a(n) of the edges, drawn randomly at each unit of time, where n is the number of vertices. Subject to certain regularity assumptions on the prescribed degree sequence, three regimes for a(n) were identified in which the mixing time has different scaling behavior as n tends to infinity. Interestingly, there is a critical regime where a(n) decays like 1/log n, in which the mixing time exhibits a so-called 'one-sided cut-off' due to a competition between static and dynamic mixing.

- Nicos Starreveld (UvA) and Andrea Roccaverde (UL), jointly with Frank den Hollander (UL) and Michel Mandjes (UvA), worked on two projects on breaking of ensemble equivalence. Their first paper focused on a random graph on which topological restrictions are imposed, such as constraints on the total number of edges, wedges, and triangles, analyzing the difference between the micro-canonical ensemble (in which the constraints are satisfied for every realization of the graph) with the canonical ensemble (in which the constraints are satisfied on average), both subject to maximal entropy. The main result, whose proof relies on large deviation theory for graphons, is that breaking of ensemble equivalence occurs when the constraints are frustrated. In a second paper, the level up to which equivalence is violated was quantified, as a function of the level of frustration.

THEME 5: DYNAMICS ON NETWORKS

While random processes in static random structures are relatively well understood, their analysis in the dynamic setting is still in its infancy. In this theme stochastic processes on randomly evolving networks are studied.

HIGHLIGHTS

- Janusz Meylahn and Frank den Hollander (UL), jointly with Diego Garlaschelli (UL and Lucca, Italy), analyzed a mathematical model for synchronization, called

the Kuramoto model, on a hierarchical network. Here, oscillators are attached to the vertices of the network and interact with each when their vertices are connected by an edge. The interaction is such that the oscillators prefer to rotate at the same frequency. Within a certain approximation scheme, a full description of synchronization on multiple space-time scales was obtained with the help of renormalization theory. In particular, three ranges of interaction parameters were identified for which there is different behavior as a function of the hierarchical level.

- Janusz Meylahn and Frank den Hollander (UL), jointly with Satya Majumdar (Paris, France), and Hugo Touchette (Stellenbosch, South-Africa), studied the scaling properties of additive functionals of Brownian motion with resetting. Resetting comes up in a variety of different contexts, including Google PageRank. Both the typical and atypical behavior of such functionals were analyzed, including anomalous large deviations.

- David Koops (UvA), jointly with Alexander Goldenshluger (Haifa, Israel), studied a statistical inference problem for a class of infinite-server queues. They provided a mathematical framework for estimating linear functionals of the service time distribution when only the number of customers can be observed, but different customers cannot be distinguished. Koops also treated the problem of estimating transaction times in the Bitcoin blockchain.

- Together with Ewan Cahen (PhD student in an NWO TOP-C1 project), Onno Boxma (TU/e), and Michel Mandjes (UvA), David Koops (UvA) studied linear stochastic fluid networks under Markov modulation. Efficient sampling algorithms with provable performance guarantees were developed. In passing, a method was obtained for recursively determining the (transient and stationary) moments of the vector of storage levels at all nodes.

- Souvik Dhara, Remco van der Hofstad, and Johan van Leeuwaarden (all at TU/e) studied critical percolation on random graphs in terms of scaling limits that describe network clusters when the network is on the verge of breaking down. They proved that there are three universality classes in terms of the power-law degree exponent, in which rather different behavior is observed for cluster sizes as well as the metric structure of critical clusters. One of the universality classes arises when the finite second-moment condition fails and the networks are so-called scale free. This creates percolation phenomena that contrast sharply with the two previously discovered universality classes.

THEME 6: TRANSPORTATION AND TRAFFIC NETWORKS

Virtually all sectors of society are facing issues regarding the design, operation, and control of highly complex networks. In this theme focus is on two key application areas: transportation and traffic networks. In some of the research projects in this theme the network structure is fixed and focus lies on the effect of the randomness involved in user behavior, while in others the main objective concerns the shaping of the network structure. Attention is paid to both structure-related issues (planning and dimensioning of transportation and traffic networks) and the operations on existing networks (such as routing and scheduling).

HIGHLIGHTS

- Pieter Kleer (CWI), together with Guido Schaefer (VU and CWI), worked on atomic congestion games to model resource allocation problems where players compete over multiple resources. The goal of the players is to choose a subset of resources that minimizes their cost, which in particular also depends on the choices of the other players. A prominent example here are network congestion games, where the available subsets of resources are paths in a given network. Kleer and Schaefer provided unifying results regarding the polynomial time computation and inefficiency (compared to a socially optimal outcome) of so-called pure Nash equilibria, which are 'stable' situations in which player can't obtain a lower cost by switching to a different path available to them in the network, or, more general, to another subset of resources available to them.

- Together with Sandjai Bhulai (VU), Wouter Kager (VU), and Michel Mandjes (UvA), Jaap Storm (PhD student at VU) studies road-traffic inspired stochastic models. A first project concerns performance analysis techniques for a rather general roundabout model. Recently, attention shifted to the use of diffusion approximations for segment-based highway models, with explicit emphasis on the development of design and control rules.

- The main theme in the PhD project of Abhishek (UvA) has been to quantify the impact of uncertainty (randomness) on the capacity and performance of road traffic systems. Road traffic performance heavily depends on the behavior of individual drivers, which is largely unpredictable and can thus naturally be described using probabilistic models. Abhishek's research revealed that due to the interaction between individual users' behaviors, as well as the random processes describing their arrivals and residing times at junctions, randomness can have both advantageous and adversarial effects. The research specifically addressed these issues in the context of unsignalized intersections, at which prioritized and nonprioritized traffic share a common infrastructure (the road intersection).Under various modeling assumptions, in projects with Marko Boon (TU/e), Onno Boxma (TU/e), Michel Mandjes (UvA), and Sindo Nunez-Queija (UvA), Abhishek quantified the capacity (in terms of traffic intensity that can be sustained by the intersection), the level of congestion (char-

GRANTS AND AWARDS

GRANTS

ERC Starting Grant
Bart Jansen for his project 'Rigorous Search Space Reduction'.

NWO TOP Grant
Frank den Hollander and Frank Redig for the project 'Duality for Interacting Particle Systems'

VICI grant
Nikhil Bansal for the project 'Making discrete decisions in a continuous way'

Robert Bosch Foundation
Harry Buhrman – PhD position on quantum computing in a practical setting

AWARDS

Humboldt Research Award
Frank den Hollander

Best Master teacher at TU/e
Mark de Berg

acterized by the stationary distribution of the number of cars queueing at the intersection), the gains of platooning of cars, the impact of the gap acceptance policy of individual drivers and the influence of impatience. These issues were addressed using various modeling and analysis techniques, including embedding of stochastic processes, queueing processes in random environments, matrix analytic analysis, phase-type modeling and heavy-traffic asymptotics.

- The work on Transportation and Traffic Networks has several connections with ongoing, more practice-oriented research projects in the vicinity of and in collaboration with NETWORKS members. In this respect we mention two projects: First, the PhD research of Daphne van Leeuwen (CWI, supervised by Rob van der Mei and Sindo Nunez Queija, and with involvement of NETWORKS postdoc Liron Ravner) on controlling/planning vehicle departure times. Second, the NWO Sustainable Logistics project Dynafloat that addresses the dynamic control of urban traffic using floating car, planning, and infrastructure data. It comprises three PhD projects, of Rik Timmerman (TU/e, supervised by Marko Boon, Onno Boxma, and Johan van Leeuwaarden), Anna Oblakova (UT, supervised by Jan-Kees van Ommeren and Richard Boucherie), and Sara Ghazanfari (CWI, supervised by Sindo Nunez Queija and Rob van der Mei, with involvement of Liron Ravner).

THEME 7: COMMUNICATION AND ENERGY NETWORKS

Communication and energy networks are both prominent instances of highly complex large-scale networked systems which are of critical importance to society. Because of their vital interest, these systems need to be designed to achieve consistently high levels of performance and reliability, and yet be cost-effective to operate. This involves huge challenges, especially since both communication and energy networks are subject to inherent uncertainty and random variation in demand as well as supply.

HIGHLIGHTS

- Murtuza Ali Abidini (TU/e) was the main organizer of the workshop “Mathematical Techniques in Optical Networks” held at EURANDOM. The workshop was very successful in creating connections between the optical networks engineering community and the mathematical community working on the performance analysis of such networks. On the research front, Abidini continued his work with his supervisors Onno Boxma, Jacques Resing and Nicola Calabretta (TU/e) on all-optical data center switches. He further finished a project (together with Boxma, Cor Hurkens, Ton Koonen, and Resing at TU/e) on revenue maximization in optical router nodes with multiple wavelengths as well as a paper (together with Jan-Pieter Dorsman (UvA) and Resing) on heavy-traffic analysis for polling systems with retrials and glue periods.

- The research of Fiona Sloothaak, with her supervisors Bert Zwart (CWI & TU/e) and Sem Borst (TU/e), has focused on macroscopic models that provide fundamental insights of how small disturbances in ener-

gy grids can lead to heavy-tailed behavior in blackout sizes. In 2018, together with fellow NETWORKS member Lorenzo Federico (TU/e), she studied non-local failure propagation in complex networks where the failure rate dynamically depends on the global structure. Besides failure dynamics in networks, Sloothaak also started and completed a project on the topic of battery-swapping infrastructure for electric vehicles, in collaboration with James Cruise and Seva Shneer (Heriot-Watt University), Maria Vlasiou (TU/e), and Bert Zwart (TU/e). Battery swapping systems provide a promising solution to reduce the high volatility in power demand in the future, and this work established adequate capacity levels that guarantee both good quality of service and near-optimal resource utilization under a dynamic control policy.

- Together with Shiva Pokhrel (University of Melbourne), Michel Mandjes (UvA) studied the dynamics of Multipath Transmission Control Protocol (MPTCP) over cellular and WiFi networks. This is a highly challenging issue because of the complex interdependencies between losses, packet reordering due to heterogeneous wireless channel features, errors, and link layer retransmissions, as well as their (joint) influence on MPTCP's control mechanism. The methodology developed in this project offers a comprehensive approach that is capable of assessing the performance of long-lived MPTCP flows with joint WiFi and cellular network access, taking the diverse characteristics of both types of networks into account.

WORKSHOPS

WORKSHOP	PERIOD	LOCATION	INVOLVED FROM NETWORKS
Mathematical Techniques in Optical Networks	April 16–18, 2018	Eurandom, Eindhoven	Murtuza Ali Abidini, Onno Boxma, Ton Koonen
Fixed Parameter Computational Geometry II	May 14–18, 2018	Lorentzcentrum, Leiden	Mark de Berg, Hans Bodlaender
Franco-Dutch (YEP) Workshop	May 28–June 1, 2018	Eurandom, Eindhoven	Remco van der Hofstad
3rd International Workshop on Highlights of Algorithms (HALG)	June 4–6, 2018	Vrije Universiteit, Amsterdam	Leen Stougie, Nikhil Bansal, Neil Olver
ISI-NETWORKS Day	June 9, 2018	Leiden University	Frank den Hollander
Critical and Collective Effects in Graphs and Networks	June 18–22, 2018	Eurandom, Eindhoven	Remco van der Hofstad, Johan van Leeuwaarden
Algorithmic and Combinatorial aspects of Partition Functions	August, 23–24, 2018	University of Amsterdam	Guus Regts, Viresh Patel
NWO-JSPS joint Seminar	September 10–14, 2018	Eurandom, Eindhoven	Hans Bodlaender
Multidimensional Queues, Risk and Finance	October 1–3, 2018	Eurandom, Eindhoven	Stella Kapodistria
YEQT XII: 'Queueing Theory and Performance Analysis of Computer and Communication Systems'	December 3–4, 2108	ENSEEIHT, Toulouse	Onno Boxma

- A thread that continued to be highly active in 2018 revolves around performance evaluation and algorithm design for large-scale data center networks and cloud systems. Mark van der Boor and Debankur Mukherjee (TU/e) have actively pursued the analysis and design of scalable load balancing algorithms. Together with their supervisors Sem Borst and Johan van Leeuwaarden (TU/e), they finished a comprehensive survey paper.

- Van de Boor completed a paper on a novel class of load-balancing algorithms where the various servers provide occasional queue updates to guide the load assignment. He demonstrated that the proposed schemes strongly outperform existing strategies, and can achieve a vanishing waiting time in the many-server limit with just one message per job. Van de Boor also investigated fluid limits for synchronous updates as well as asynchronous exponential update intervals, and used the fixed point of the fluid limit to derive the queue length distribution in the latter case.

- Mukherjee finalized a paper on the performance of load balancing algorithms in network scenarios as represented by some underlying graph topology, and identified a broad class of asymptotically optimal topologies. The paper was presented at the ACM SIGMETRICS 2018 conference, where it received the Best Student Paper award.

- The research of Youri Raaijmakers (TU/e) focuses on the performance and stability of server selection and task replication algorithms in parallel-server systems, in particular so-called redundancy scheduling policies and stochastic learning approaches. The initial results of Raaijmakers' research resulted in two papers which are to appear in the journals *Performance Evaluation and Queueing Systems*.

PORTFOLIOS

NETWORK PAGES

The Network Pages are an interactive web portal aimed at a broad audience interested in network science. The slogan `The math and algorithms that keep us connected. Network science for students, teachers and researchers' describes the content as well target audiences of the site. The Network Pages also provide a forum to reach high-school teachers and students, for example through the 'Networks goes to school' masterclasses, for which the material is advertised on the Network Pages.

From December 2016 onwards, the aim was to publish an article every month and a blog bi-weekly. In 2018, Nicos Starreveld joined the team, and has effectively professionalized the process of article gathering. Starreveld now maintains an active pipeline. In 2018, we have started professionalizing the writing of content through 'Analytic Story Telling' workshops, which prepare the participants in writing articles, and help them to bridge the gap between their usual academic writing and the more outreach style that is wanted at the Network Pages. The first 6 participants have used this experience to write an article. In 2019, we continue our 'Analytic Story Telling' workshops, aiming for two more sessions. We plan to enhance the visibility of the site and aim to take the next step in increasing the number of videos on the site, gaining from our experiences in the past year.

VALORIZATION

The research activities in NETWORKS are not only driven by intriguing scientific quests, but also strongly inspired by urgent challenges involving complex dynamic networks that industry and society are increasingly being confronted with. Several paths are being pursued to accomplish the transfer of novel insights and results and translate fundamental concepts into actual implementations.

Specifically, the main vehicles for knowledge transfer and utilization are:

(i) a long-term flux of young talented professionals trained in the various groups in NETWORKS;
(ii) active engagement of the NETWORKS groups in broader efforts to promote the application of advanced knowledge in mathematics and computer science to solve problems of industrial and societal relevance;
(iii) close ties maintained by many of the principal investigators in NETWORKS with companies and societal organizations, and involvement in application-oriented multi-disciplinary projects;
(iv) open, high visibile channels towards companies and societal organizations that face challenges relating to complex dynamic networks and seek innovative solution approaches.

There are successful interactions with TNO, which is a semi-public organization in applied scientific research with an active interest in the various application areas pursued by NETWORKS, in particular societal infrastructure networks. Michel Mandjes and Sem Borst have continued their fruitful contacts and research collaborations with Hans van den Berg at TNO on several topics of common interest. In particular, collaboration with Van den Berg has been initiated on the topic of self-learning resource allocation schemes for next-generation wireless networks in the context of the PhD project of Bart Post (TU/e). Opportunities for a future joint PhD project with TNO in the area of data-driven wide-area scheduling in cellular networks with user mobility are under active investigation. In addition, TNO and UvA have jointly

appointed a PhD student who is working on the design and control of road traffic networks.

NETWORKS played a central role in the organization of the 2018 edition of the "Study Group Mathematics with Industry" event held at Eindhoven University of Technology, with Stella Kapodistria acting as one of the main organizers and several further NETWORKS members participating in the week-long program. The problems that were pursued included a specific networks-oriented problem formulated by the company CQM on optimal order picking strategies in warehouses, for which a highly innovative solution was presented.
Several principal investigators of NETWORKS are engaged in application-oriented projects which are typically carried out in the framework of the Topsector themes of the Dutch government, special industrial partnerships, or various local initiatives. There are in particular long-standing collaboration efforts between TU/e and Philips (e.g. Data Science and Lighting Flagship programs) and between TU/e and UvA with SURFnet. NETWORKS also continues to explore connections with various routes of the Nationale Wetenschapsagenda (NWA) and forge novel links with non-traditional application domains such as social sciences.

INTERNATIONALIZATION

NETWORKS continued its successful collaboration with the Indian Statistical Institute (ISI). In January 2018 a workshop was organized at the ISI in Kolkata, which was attended by 30 researchers from India and 10 researchers from the NETWORKS community. Afterwards, Matteo Sfragara (UL) stayed at ISI Kolkata for one month to collaborate with ISI's Arijit Chakrabarty and Rajat Hazra in a joint project with Frank den Hollander on spectra of random networks. Before the workshop, Frank den Hollander and Michel Mandjes visited the Tata Institute in Mumbai and gave lectures. On June 9, 2018, a 1-day workshop was organized in Leiden, with 4 members of ISI who were visiting Europe for conferences. The workshop was attended by 10 members from NETWORKS. Rajat Hazra visited Delft and Leiden in June 2018. Several further visits are planned for 2019.

The exchange between NETWORKS and ACEMS, the Australian Research Council (ARC) Centre of Excellence for Mathematical and Statistical Frontiers, also proceeded well. Jointly with Jerzy Filar, Thomas Taimre, and Yoni Nazarathy (University of Queensland) and Vivek Borkar (IIT Mumbai), Michel Mandjes was awarded an Australian ARC Discovery grant. PhD Student Brendan Patch completed his PhD thesis, which will be defended early 2019 (jointly at the University of Queensland and UvA). Several mutual visits are planned for 2019, in particular, around the INFORMS Applied Probability conference, which will be held in Brisbane in July 2019. ACEMS set up a program that financially supports junior staff who want to visit NETWORKS researchers.

EDUCATION

Two main components of the NETWORKS educational program are the Training Weeks and the internships.

In the Training Weeks, researchers from NETWORKS gather to learn more about the research topics studied within the entirety of the NETWORKS project. The Training Weeks not only play an important role in the education of PhD students, they also help to connect (researchers from) stochastics and algorithms. In their current setting, the morning sessions of the Training Weeks are typically dedicated to two mini-courses on topics studied within the projects, while the afternoon is used for presentations by NETWORKS researchers—PIs, tenure trackers, postdocs and PhD students—on their latest research, an Open Problem Session, and working sessions where participants work together in new or existing research collaborations.

We have settled into a schedule with two Training Weeks each year, one in the spring and one in the fall. The former takes place in Kaap Doorn (in Doorn), the latter in De Schildkamp (in Asperen). Both are beautiful locations with a variety of options to relax and socialize. The 2018 Spring Training Week was held April 9-13, with mini-courses by Jan-Pieter Dorsman (UvA) and Jop Briët (CWI). Jan-Pieter's mini-course was about stochastic simulation, a topic that is highly relevant for both stochastic as well as algorithms researchers. Jop lectured on applications of Grothendieck's Inequality, showing how it relates results from many seemingly unrelated areas to each other. The 2018 Fall Training Week was held October 29—November 3. For the first time one of the mini-courses was given by an external speaker, namely Joel Spencer (CIMS NYU). Joel gave wonderful presentations on probabilistic method and random graphs. The second mini-course was by Nikhil Bansal (TU/e), who covered algorithmic techniques to deal with extremely large volumes of (streaming) data.

The NETWORKS internships are small (2 to 3-months) research projects. Many PhD students do their internship with another research group in NETWORKS, but it is also

'NETWORKS day', September 2018

an option to visit a research group abroad or an applied research institution. The internships not only serve to broaden the knowledge of the PhD students, but also to foster collaborations between researchers from different research areas. They already led to several new results on the interface between algorithmics and stochastics.

OUTREACH

In 2018 several new outreach activities have been organized.

On 18 and 23 April a masterclass event in two parts on networks and their applications was organized at Leiden University and the University of Amsterdam. Under the title 'NETWORKS goes to school', the event aimed to introduce secondary school students with an interest in mathematics to mathematics education at a university and to provide them further deepening in their mathematical knowledge. Another goal was to give PhD candidates the opportunity to disseminate their scientific research. Since this was the first masterclass held in English, it was accessible to international schools as well. About 25 students from international schools from Amsterdam, Oegstgeest, Rotterdam, and The Hague participated in the event.
The program consisted of lectures, discussions, games, reading sessions, and interactive group activities. On April 18 the event started at Leiden University. Clara Stegehuis (TU/e) talked about Social Networks and Janusz Meylahn (UL) gave a lecture about Neural Networks. On April 23 the second part of the masterclass took place in Amsterdam. The day started with a guided tour in the Science Park main building followed by a series of lectures by Birgit Sollie (VU) about Networks in Biology and by Jan-Pieter Dorsman (UvA) about the Markov Chain. In December 2018 a booklet with all the material of the masterclass was published and distributed among secondary schools.

In addition, under the umbrella of KNAW, we organized in November a thematic evening for a broad audience at the public library of Amsterdam. Engaging talks were given by Jacobien Carstens (UvA), Stella Kapodistria (TU/e), Monique Laurent (CWI), and Nelly Litvak (TU/e). The lectures can be watched at www.knaw.nl/nl/actueel/agenda/netwerken.

HIGHLIGHT

SPECIAL ISSUE OF JOURNAL OF STATISTICAL PHYSICS DEVOTED TO COMPLEX NETWORKS

A special issue of the *Journal of Statistical Physics* was published in November, devoted to complex networks. Editors of this special issue were Diego Garlaschelli (UL), Remco van der Hofstad (TU/e), Frank den Hollander (UL), and Michel Mandjes (UvA). The idea for this special issue arose from the outreach activities of NETWORKS. The issue contains 30 papers written by leading researchers in the field. The papers are organized according to three classes of topics:

- Structure of Static and Dynamic Random Graphs
- Random Processes on Random Networks
- Applications of Networks

You can find the titles and brief descriptions of each of the papers at link.springer.com/article/10.1007%2Fs10955-018-2166-y.

HIGHLIGHT

FIRST NETWORKS PHD GRADUATES RECEIVE CUM LAUDE DISTINCTION

August 28, 2018 was a special day for NETWORKS since the very first NETWORKS PhD students defended their PhD theses. Souvik Dhara and Debankur Mukherjee not only graduated on the same day, but also both received the *cum laude* distinction.

Debankur Mukherjee

Debankur Mukherjee received the *cum laude* distinction for his PhD thesis entitled 'Scalable Load Balancing in Networked Systems'. The thesis contains a stunning collection of ground-breaking results at the frontier of a booming and highly competitive domain of research. Debankur has in particular pioneered the notion of asymptotic optimality and universality of load balancing algorithms, as an overarching perspective on scalability issues in large-scale data centers. The exceptional quality of the thesis is reflected by an impressive record of publications in top-notch journals, such as *Annals of Applied Probability*, *Journal of Applied Probability*, *Mathematics of Operations Research*, and *Stochastic Systems*, as well two papers at the highly prestigious and selective ACM SIGMETRICS Conference, one of which received the Best Student Paper Award in June.

Souvik Dhara

Souvik Dhara received the *cum laude* distinction for his PhD thesis entitled 'Critical Percolation on Random Graphs with Prescribed Degree Sequences'. The thesis gives an impressively complete description of the possible behaviors of critical percolation on random graphs, in which the degree sequence is fixed. Souvik's work is remarkably deep, and many of the concepts and techniques far transcend the context of the specific models. The results are also mathematically sophisticated, original, and of consistently high quality, as evidenced by the fact that they have led to several publications in major journals, in particular the *Electronic Journal of Probability* and the *Journal of Statistical Physics*, as well as in the ACM SIGMETRIC Conference.

Debankur Mukherjee (left) and Souvik Dhara

ORGANIZATIONAL ASPECTS

ORGANIZATIONAL DEVELOPMENTS

In 2018, 2 PhD students and 1 postdoc have been appointed. Frits Spieksma (TU/e) succeeded Nikhil Bansal in the Project Team of NETWORKS. Leen Stougie (CWI) joined the Management team as a successor of Lex Schrijver, who will retire early 2019. In the support staff, Tiny Dekker (UvA) succeeded Monique Onderwater; Nicos Starreveld (UvA) was part-time appointed as coordinator of the Network Pages and outreach activities.
By the end of 2018, NETWORKS counted 60 members and 38 affiliated members (who are not paid by the grant but are strongly connected to the NETWORKS program).

NETWORKS members and affiliated members convene two or three times a year during the so-called NETWORKS days. In 2018 the first NETWORKS day consisted of a meeting with the Scientific Advisory Board (SAB). This panel provided us with thoughtful and constructive advice, on both purely scientific and organizational aspects. During the first day, the scientific aspects of the program were highlighted by research presentations from both the NETWORKS members and the members of the SAB. On the second day, round-table discussions were organized on the themes of valorization, gender diversity, interdisciplinarity, outreach, and the opportunities for continuation of the program after 2024.

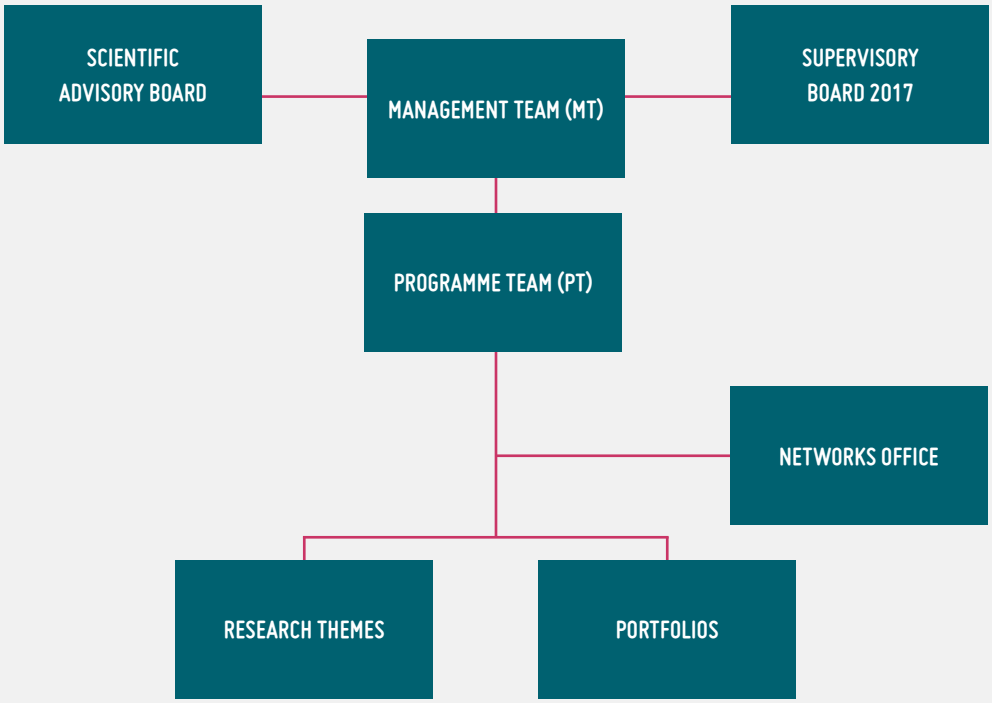
In September 2018 the second NETWORKS day was organized in Leiden in the usual way with various lectures. Keynote lectures were given by Iman van Lelyveld (De Nederlandsche Bank and Vrije Universiteit Amsterdam) and Shankar Bhamidi (University of North Carolina).

PHD DEFENCES

PHD STUDENT	DEFENSE DATE	UNIVERSITY	THESIS TITLE	PROMOTORES
Andrea Roccaverde	December 12, 2018	(UL)	Breaking of Ensemble Equivalence for Complex Networks	Frank den Hollander, Diego Garlaschelli
Souvik Dhara	August 28, 2018	(TU/e)	Critical Percolation on Random Networks with Prescribed Degrees	Remco van der Hofstad, Johan van Leeuwaarden
Debankur Mukherjee*	August 28, 2018	(TU/e)	Scalable Load Balancing Algorithms in Networked Systems	Sem Borst, Johan van Leeuwaarden

* affiliated PhD-student

ORGANOGRAM



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prof. dr. Sem Borst (TU/e)
prof. dr. Remco van der Hofstad (TU/e)
prof. dr. Frank den Hollander (UL)
prof. dr. Michel Mandjes (UvA, chair)
prof. dr. Lex Schrijver (UvA, CWI)

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prof. dr. Mark de Berg (TU/e)
prof. dr. ir. Sem Borst (TU/e)
prof. dr. ir. Onno Boxma (TU/e)
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prof. dr. Remco van der Hofstad (TU/e)
prof. dr. Frank den Hollander (UL)
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Marieke Kranenburg, project manager
Patty Koorn, workshop officer
Petra Rozema, secretary
Tiny Dekker, webmaster
Bart Groeneveld, outreach
Nicos Starreveld, outreach

PORTFOLIOS

Workshops
Outreach
Internationalization
Education
Valorization
Network Pages

RESEARCH THEMES

Approximate and exact network methods
Spatial networks
Quantum networks
Dynamics of networks
Dynamics on networks
Transportation and traffic networks
Communication and energy networks

NETWORKS MEMBERS

AFFILIATION ABBREVIATED	FULL NAME WITH TITLE	FUNCTION PROFILE
UvA	Abhishek, MSc	PhD-student
TU/e	Murtuza Ali Abidini, MSc	PhD-student
CWI	dr. Georgios Amanatidis	Postdoc
UL	dr. Luca Avena	Tenure Track
CWI	Tom Bannink, MSc	PhD-student
TU/e	prof.dr. Nikhil Bansal	Professor
TU/e	prof.dr. Mark de Berg	Professor
TU/e	Pascalle van den Berg	Support Staff
TU/e, UU	prof.dr. Hans Bodlaender	Professor
TU/e	Mark van der Boor, MSc	PhD-student
TU/e	prof.dr.ir. Sem Borst	Professor
TU/e	prof.dr.ir. Onno Boxma	Professor
CWI	dr. Jop Briët	Tenure Track
CWI	Ruben Brokkelkamp, MSc	PhD-student
UvA, CWI	prof.dr. Harry Buhrman	Professor
UvA	dr. Jacobien Carstens	Postdoc
UL	dr. Conrado Da Costa	Postdoc
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UvA	dr. Jan-Pieter Dorsman	Tenure Track
TU/e	Lorenzo Federico, MSc	PhD-student
TU/e	dr. Robert Fitzner	Programmer
TU/e	Alessandro Garavaglia, MSc	PhD-student
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UvA	Mariska Heemskerk, MSc	PhD-student
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UL	prof.dr. Frank den Hollander	Professor
TU/e	dr. Tim Hulshof	Tenure Track
TU/e	dr. Bart Jansen	Tenure Track
TU/e	dr. Stella Kapodistria	Tenure Track
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TU/e	Sándor Kisfaludi-Bak, MSc	PhD-student
CWI	Pieter Kleer, MSc	PhD-student
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TU/e	dr. Sándor Kolumbán	Postdoc
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UvA	prof.dr. Michel Mandjes	Professor
TU/e	Aleksandar Markovic, MSc	PhD-student
UL	Janusz Meylahn, MSc	PhD-student
TU/e	dr. Jesper Nederlof	Tenure Track
UvA	prof.dr. Sindo Núñez Queija	Professor
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UL	Margriet Oomen, MSc	PhD-student
UvA	Brendan Patch, MSc	PhD-student
UvA	dr. Viresh Patel	Tenure Track
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TU/e	Bart Post, MSc	PhD-student
TU/e	Youri Raaijmakers, MSc	PhD-student
TU/e, UvA	dr. Liron Ravner	Postdoc
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TU/e	Petra Rozema-Hoekerd	Support Staff
CWI, UvA	prof.dr. Lex Schrijver	Professor
UL	Matteo Sfragara, MSc	PhD-student
TU/e	Fiona Sloothaak, MSc	PhD-student
VUA	Birgit Sollie, MSc	PhD-student
UvA	Nicos Starreveld, MSc	PhD-student
VUA	Jaap Storm, MSc	PhD-student
CWI	prof.dr. Leen Stougie	Professor
UL, TU/e	Marjolein de Vries, MSc	PhD-student

See www.thenetworkcenter.nl/people/people-overview for extended profiles

AFFILIATED MEMBERS

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TU/e	prof.dr.ir. Ivo Adan	Staff
VUA	dr. René Bekker	Staff
VUA	prof.dr. Sandjai Bhulai	Staff
UvA	dr. Arnoud den Boer	Tenure Track
TU/e	dr.ir. Marko Boon	Staff
TU/e	dr. Kevin Buchin	Staff
TU/e	Ellen Cardinaels, MSc	PhD-student
CWI	dr. Daniel Dadush	Tenure Track
UU	prof.dr. Roberto Fernandez	Staff
UL	dr. Diego Garlaschelli	Staff
TU Delft	dr. Dion Gijswijt	Staff
VUA	prof.dr. Mathisca de Gunst	Staff
CWI	dr. Stacey Jeffery	Tenure Track
TU/e	Joost Jorritsma, MSc	PhD-student
VUA	dr. Wouter Kager	Staff
TU/e	dr. Júlia Komjáthy	Tenure Track
CWI	prof.dr. Monique Laurent	Staff
UT	prof.dr. Nelly Litvak	Staff
TU/e	Debankur Mukherjee, MSc	PhD-student

AFFILIATION ABBREVIATED	FULL NAME WITH TITLE	FUNCTION PROFILE
TU/e	dr. Francesca Nardi	Staff
CWI, VUA	dr. Neil Olver	Staff
TU/e	dr. Rudi Pendavingh	Staff
UvA	dr. Guus Regts	Tenure Track
TU/e	dr. Jacques Resing	Staff
CWI, VUA	prof.dr. Guido Schäfer	Staff
UL	prof.dr.ir. Ionica Smeets	Staff
TU/e	prof.dr. Bettina Speckmann	Staff
UL	dr. Floske Spieksma	Staff
TU/e	Clara Stegehuis, MSc	PhD-student
UvA	Fabian Stroh, MSc	PhD-student
TU/e	Viktória Vadon, MSc	PhD-student
UL	prof.dr. Evgeni Verbitskiy	Staff
TU/e	dr. Maria Vlasiou	Staff
UvA	dr. Neil Walton	Staff
Germany	prof.dr.ing. Gerhard Woeginger	Staff
UU	Tom van der Zanden, MSc	PhD-student
UL	Qi Zhang, MSc	PhD-student
CWI, TU/e	prof.dr. Bert Zwart	Staff

PHD PROJECTS

PHD STUDENT	PROJECT TITLE	SUPERVISORS	AFFILIATION
Murtuza Ali Abidini	Optical Networks	Onno Boxma, Ton Koonen, Jacques Resing	TU/e
Abhishek	Optimisation of polling networks with limited service disciplines	Sindo Núñez Queija, Marko Boon, Michel Mandjes, Onno Boxma	UvA
Bannink, Tom	Quantum Walks and Quantum Algorithms	Harry Buhrman, Jop Briët, Frank den Hollander	CWI
Mark van der Boor	Load Balancing Algorithms in Networked Systems	Sem Borst, Johan van Leeuwaarden	TU/e
Ruben Brokkelkamp	Network Optimization under Strategic Behaviour and Data Uncertainties	Guido Schäfer	CWI
Souvik Dhara	Information diffusion and epidemics on random graphs	Remco van der Hofstad, Johan van Leeuwaarden	TU/e
Lorenzo Federico	Invasion percolation and minimal spanning trees on spatial graphs	Remco van der Hofstad, Frank den Hollander	TU/e
Alessandro Garavaglia	Citation networks and performance measures	Remco van der Hofstad, Gerhard Woeginger	TU/e
Hakan Güldas	Random processes on dynamic random graphs	Frank den Hollander, Remco van der Hofstad, Luca Avena	UL
Mariska Heemskerk	Correlated sources in networks	Michel Mandjes, Johan van Leeuwaarden	UvA
Madelon de Kemp	Optimized Appointment Scheduling	Michel Mandjes, Neil Olver	UvA
Sándor Kisfaludi-Bak	FPT algorithms for geometric network problems	Mark de Berg, Hans Bodlaender	TU/e
Pieter Kleer	Refined Models and Coordination Mechanisms for Network Games	Guido Schäfer, Lex Schrijver	CWI
David Koops	Scaling limits of random walks	Michel Mandjes, Onno Boxma	UvA
Lucas van Kreveld	Resource allocation in stochastic networks	Michel Mandjes, Jan-Pieter Dorsman, Onno Boxma	UvA
Farrokh Labib	Unknown	Jop Briët	CWI
Aleksandar Markovic	Algorithms for Range- and Frequency-Assignment Problems in Wireless Networks	Gerhard Woeginger, Mark de Berg	TU/e
Janusz Meylahn	Spontanenous synchronization in complex networks	Frank den Hollander, Diego Garlaschelli, Joke Meijer	UL
Daniel Olah	Robust Spanner Networks in the Face of Uncertainty	Mark de Berg, Remco van der Hofstad, Tim Hulshof	TU/e

More PhD projects on the next page »

PHD PROJECTS (CONTINUATION)

PHD STUDENT	PROJECT TITLE	SUPERVISORS	AFFILIATION
Margriet Oomen	Spatial populations with seed-bank	Frank den Hollander, Andreas Greven	UL
Brendan Patch	Stability and control of transportation and communication networks	Michel Mandjes, Thomas Taimre	UvA , UQ
Astrid Pieterse	Parameterized Preprocessing for Network Analysis Problems	Bart Jansen, Mark de Berg	TU/e
Bart Post	Dynamic resource allocation and user association in pico-cell networks	Sem Borst, Ton Koonen, Gerhard Woeginger	TU/e
Youri Raaijmakers	Speed Scaling	Sem Borst, Onno Boxma	TU/e
Andrea Roccaverde	Breaking of ensemble equivalence for complex networks	Frank den Hollander, Diego Garlaschelli	UL
Matteo Sfragara	Dynamic behavior of interacting-particle systems with hard-core interaction	Frank den Hollander, Sem Borst, Francesca Nardi	UL
Fiona Sloothaak	Dynamic interaction and volatility in future energy networks	Sem Borst, Bert Zwart	TU/e
Birgit Sollie	Statistical inverse problems for network dynamics	Michel Mandjes, Mathisca de Gunst, Bartek Knapik	VUA
Nicos Starreveld	Interpretation of measurements for distributed control	Michel Mandjes, René Bekker	UvA
Jaap Storm	Stochastic models for road traffic	Michel Mandjes, Sandjai Bhulai, Wouter Kager	VUA
Fabian Stroh	Hamilton cycles in sparse graphs	Viresh Patel	UvA

PUBLICATION HIGHLIGHTS

- Intertwining wavelets or multiresolution analysis on graphs through random forests
  Avena, L., Castell, F., Gaudillière, A. & Mélot, C., *Applied and Computational Harmonic Analysis*, DOI: 10.1016/j.acha.2018.09.006

- Mixing times of random walks on dynamic configuration models
  Avena, L., Güldas, H., van der Hofstad, R. & den Hollander, F., *The Annals of Applied Probability*, 28(4), pp 1977–2002

- An ETH-Tight Exact Algorithm for Euclidean TSP
  de Berg, M., Bodlaender, H.L., Kisfaludi-Bak, S., Kolay, S., In: *Proceedings of the 59th Annual IEEE Symposium on Foundations of Computer Science (FOCS 2018)*, pp 450–461

- Networks of fixed-cycle intersections
  Boon, M.A.A. & van Leeuwaarden, J.S.H., *Transportation Research Part B: Methodological* (117), pp 254–271

- Ensemble equivalence for dense graphs
  den Hollander, F., Mandjes, M., Roccaverde, A., & Starreveld, N.J., *Electronic Journal of Probability, Vol. 23*, paper no. 12

- High-capacity optical wireless communication using 2-dimensional IR beam steering
  Koonen, A.M.J., Gomez-Agis, F., Huijskens, F., Mekonnen, K.A., Cao, Z. & Tangdiongga, E., *Journal of Lightwave Technology (36)19*, pp 4486–4493

- Infinite-server queues with Hawkes input
  Koops, D.T., Saxena, M., Boxma, O.J., & Mandjes, M., *Journal of Applied Probability, 55(3)*, pp 920–943

- Round-robin tournaments generated by the Circle Method have maximum carry-over
  Lambrechts, E., Ficker, A., Goossens, D. & Spieksma F.C.R., *Mathematical Programming 172*, pp 277–302

- Asymptotically optimal load balancing topologies
  Mukherjee, D., Borst, S.C. & van Leeuwaarden, J.S.H., *Proceedings of the ACM on Measurement and Analysis of Computing Systems* 2 (1)
  Received ACM SIGMETRICS 2018 Best Student Paper Award

- Gaussian Width Bounds with Applications to Arithmetic Progressions in Random Settings
  Briët, J. and Gopi, S.
  International Mathematics Research Notices, rny238 (2018)

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