THE NETWORKS-COFUND PROJECT

PROJECT

Information Package for PhD Applicants

The NETWORKS project is a collaboration of world-leading researchers from four institutions in The Netherlands – TU Eindhoven, University of Amsterdam, Leiden University and the Centrum Wiskunde & Informatica (CWI) – focusing on the stochastics and algorithmics behind network problems. It offers a highly stimulating research environment and an extensive training program for PhD students from all over the world. Recently NETWORKS was awarded a COFUND grant from the Marie Skłodowska-Curie Actions (MSCA), funded by the European Commission. The grant allows NETWORKS to expand its activities by opening positions for an additional 14 international PhD students.
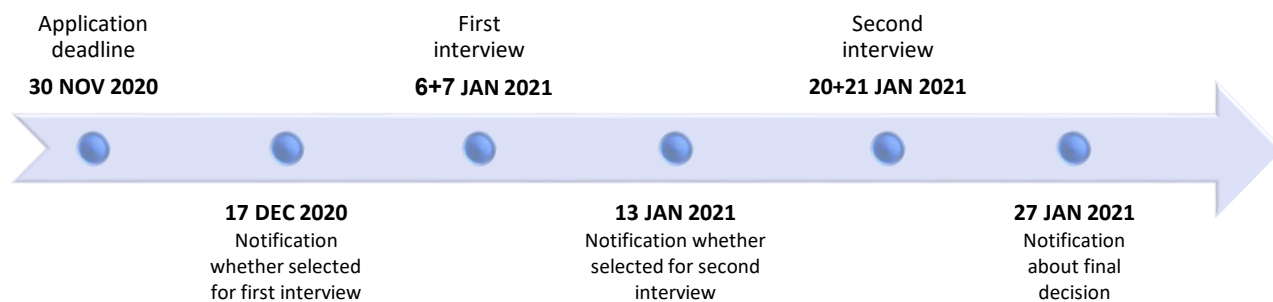
The NETWORKS PhD students

The 14 PhD students will be recruited in three calls: the first call was organized in spring 2020, the second call is right now and the third call will open in February 2021. In this document you can find more information about the research themes studied in the project, the potential supervisors, and the application procedure including eligibility criteria.

Contents

Overview of selection process and important dates

In a nutshell, the selection process is as follows. After the application deadline (November 39), the Selection Committee will make a longlist of candidates who will be invited for a first interview. Based on these first interviews, the Selection Committee will make a shortlist of candidates who will be invited for a second interview. After these second interviews, a final decision will be made about whether you will receive an offer for one of the available PhD positions. The dates of the various steps in the process of thi second call are listed below.

Application deadline	First interview	Second interview
30 NOV 2020	**6+7 JAN 2021**	**20+21 JAN 2021**

| | **17 DEC 2020**
Notification whether selected for first interview | | **13 JAN 2021**
Notification whether selected for second interview | | **27 JAN 2021**
Notification about final decision |

Possible research projects for PhD students

Research in NETWORKS focuses on stochastics (including queueing theory, random graphs, stochastics processes, stochastic optimization) and algorithmics (including computational geometry, graph theory and algorithms, combinatorial optimization, quantum algorithms) for network problems. As a NETWORKS-COFUND PhD student you can define your own PhD project in this broad area, in collaboration with your supervisor. Hence, in your application you should already indicate the supervisor(s) with whom you would like to work. When you are selected to join the NETWORKS project, you will develop the topic of your research project together with your supervisor in the first few months of your appointment.

For more information on potential supervisors and their research interests, see Appendix A: Potential NETWORKS supervisors and their research areas*.*

Research opportunities and Training Program

The core of your PhD studies will be to perform research, in collaboration with and coached by your supervisor. NETWORKS offers an excellent environment for this. In addition to the main supervisor, you will be assigned a second supervisor who brings in additional expertise. Supervisors work very closely with their PhD students, to maximize the quality of the research. You will also have a generous travel budget, allowing you to visit international conferences, workshops and summer schools. Moreover, each PhD student has the opportunity to make one or two research visits to universities outside The Netherlands. The visits will last two weeks or more, and the host university is chosen depending on your own specific research topic.

NETWORKS offers an extensive and inspiring training program. The program includes the components listed below. In addition, there are several other NETWORKS events that you can participate in.

Training Weeks. NETWORKS organizes two Training Weeks per year. The morning sessions in each Training Week are devoted to two *mini-courses*, one on a topic from stochastics and the other on a topic from algorithmics. The afternoon sessions feature *research presentations* by NETWORKS researchers (PIs or other staff members, postdocs and PhD students) about their current work, and *working sessions* where participants can collaborate on research problems. The Training Weeks are held at off-campus locations, to maximize social interaction and community building among the NETWORKS researchers.

Community building event

Industrial Internships. Each PhD student will do an internship of 2-3 months in a non-academic environment, typically in the second or third year of her/his PhD.

Professional skills courses. There is a variety of courses on professional skills and personal development available to NETWORKS PhD students. These include courses on technical writing and giving presentations, developing teaching skills, personal effectiveness, and more. Together with your supervisor, you decide on a personal course program.

The research and training program of NETWORKS offers you excellent opportunities for a future career, be it in academia, government, or industry. NETWORKS graduates found jobs at top academic institutions both in and outside Europe (including MIT, Georgia Tech, Warwick University, and Max-Planck-Institut für Informatik), at major multinationals in the high-tech and financial industry (including Microsoft, Google, PriceWaterhouseCoopers and ABN-AMRO) and at medium-size companies and start-ups.

PhD graduation ceremony

Being a PhD student in the Netherlands

In the Netherlands, every PhD student gets paid a salary; no additional grants are needed. Moreover, even though NETWORKS offers an extensive training program that allows you to expand your knowledge and skills (see above), there are no exams or course requirements. Hence, PhD students are more like employees than like students. Your work as a PhD student may include being a teaching assistant (TA) in BSc or MSc courses offered at your institution. This amounts to up to 15% of the time; the remaining time is spent on research and research-related activities such as the training program. As an international PhD student you need not speak Dutch: it is easy to get by with English, not only at the university but also in everyday life.

Selection criteria

We are looking for enthusiastic and motivated applicants with a background in mathematics (in particular stochastics) and an affinity for computer science, or with a background in computer science (in particular algorithms) with affinity for mathematics. You should have an MSc degree or be close to obtaining it. The evaluation criteria are:

- Research potential (grades, creativity and independence): 40%
- Verbal and oral communication skills (in English): 20%
- Educational background and other experience: 20%
- Commitment and enthusiasm: 20%

Application procedure and eligibility criteria

In order to be eligible, make sure you send **your complete application before the deadline** of the call. At the starting date of your employment as a PhD student in the NETWORKS COFUND program, you should be in possession of an MSc degree. Moreover, you meet the mobility requirement of the MSCA which encourages transnational, intersectoral and interdisciplinary mobility. The mobility requirement is: You may not have resided or carried out your main activity (work, studies, etc.) in the Netherlands for more than twelve months in the three years immediately before the starting date of your employment.

Applications should be done through the online system available at the NETWORKS website. You should fill in the online application form and **provide the following documents combined in one pdf**, in English:

- A motivation letter that, among other things, mentions the research theme(s) you are interested in and/or the NETWORKS supervisor(s) you would like to work with (see Appendix A and B);
- A CV including (if applicable) a list of publications and experience with teaching;
- A copy of your MSc diploma or a transcript specifying the number of credits they thus far obtained in their MSc studies and a list of grades for your MSc courses.

In the online application system you can supply the names and email addresses of up to three references, who will be contacted by us for recommendation letters.

Diversity and equal-opportunities policy

NETWORKS values an inclusive and diverse working environment, and we encourage all candidates to apply, irrespective of their gender, religion, sexual orientation or disabilities. When evaluating the candidates, we will take parental leave and other personal circumstances into account, and we will strive for a diverse composition of the appointed PhD students.

Employment conditions and support

As a PhD student in the NETWORKS-COFUND program, you will be appointed at the institution of your main supervisor (TU Eindhoven, University of Amsterdam, Leiden University, or CWI). Appointments at TU/e, UvA and LU will follow the Collective Employment Agreement (CAO) of Dutch Universities, and the appointments at CWI will follow the CAO for Research Centres (which is essentially the same). Gross salary ranges from € 2.395 per month in the first year increasing up to € 3.061 in the fourth year. All institutions offer a broad package of fringe benefits.

The HR department of the institution where you will be employed will assist you in obtaining a visa and work permit if needed. They can also help you when looking for housing.

Appeal procedure

If you feel your application has been rejected on improper grounds, you can appeal the decision. You should do so within 14 days of the decision by sending an email to the Managing Director of the Department of Mathematics and Computer Science at TU Eindhoven, dr. R.C. van der Drift (R.C.v.d.Drift@tue.nl).

Contact

If you have any questions, please contact info@thenetworkcenter.nl.

Appendix A: Potential NETWORKS supervisors and their research areas

Below is an alphabetical list of all potential NETWORKS supervisors of PhD projects for this second call (October 2020), with their research profiles.

Luca Avena (Leiden University)

Luca Avena's research activity is in probability theory with a focus on problems coming from statistical physics and network science, related to the theory of so-called random walks and disordered media. Fundamental interests are on the rigorous analysis of models of random motion in non-homogeneous networks with possibly random space-time features. From a more applied side, he has been recently active in developing randomized exploration algorithms for network data sets using random walks and related random combinatorial objects such as rooted spanning trees and forests. Both these fundamental and more applied lines of investigation heavily rely on a deep understanding of the delicate interplay between the behaviour of Markovian dynamics on a given graph and the spectral properties of the associated adjacency and Laplacian matrices. A possible topic for a PhD project is to clarify some aspects of this delicate interplay by looking at scaling properties of spectra associated with key complex network models. Mathematical techniques that will be used come from probability theory, combinatorics and functional analysis. The PhD projects will be co-supervised by Frank den Hollander and Rajat Hazra (Leiden University).

Mark de Berg (TU Eindhoven)

Mark de Berg's research focuses on algorithms and data structures for spatial data. Spatial data—points, lines, or other geometric objects in 2- or higher-dimensional space – play an important role in many application areas and give rise to challenging algorithmic problems. A central theme in Mark de Berg's work is the question: How can we exploit the properties that real-world spatial data sets often possess to obtain provably efficient algorithms? Possible topics for PhD projects include geometric network problems that lie at the interface of computational geometry and combinatorial optimization. A PhD student working on this topic would be co-supervised with Frits Spieksma.

Sem Borst (TU Eindhoven)

The research activities of Sem Borst focus on evaluating and optimizing the performance and reliability of large-scale systems that operate under randomness and uncertainty. Typical examples of such systems are communication networks like the Internet, data centers, energy systems, supply chains, transportation networks and hospital operations. While the research topics are strongly inspired by applications, the approach is foundational in nature and driven by mathematical rigor. Key methodological tools in the analysis are stochastic processes, random walks, queueing theory and asymptotic scaling methods. The optimization involves distributed control, resource allocation and scheduling algorithms, with data-driven optimization and stochastic learning techniques playing an increasingly prominent role as well. Possible topics for PhD projects include load balancing and robust dimensioning in data centers and skill-based service systems, stochastic learning techniques for matching tasks with servers, data-driven optimization of resource allocation mechanisms, and design of efficient control algorithms for autonomous driving.

Jop Briët (Centrum Wiskunde Informatica)

Jop Briët does interdisciplinary research that combines areas including quantum information theory, additive combinatorics and Fourier analysis and Banach / operator spaces. Examples of how these areas meet include using classical operator space results to characterize quantum algorithms in terms of multivariate polynomials and applying additive combinatorics techniques in the study of quantum entanglement. His current interests include developing non-commutative branches additive combinatorics and of Fourier analysis over the boolean hypercube. Possible topics for PhD projects include (1) further developing the quantum polynomial method to prove new lower bounds on quantum algorithms, find faster ones and determining the need for structure in quantum speed-ups, and (2) to further develop non-commutative analogues of the Gowers inverse theorems from additive combinatorics and trying to apply these to devise new ways of testing supposed quantum devices.

Frank den Hollander (Leiden University)

Research of Frank den Hollander is on probability theory, with a focus on interfaces with statistical physics, population genetics and complex networks. This includes the study of phase transitions and other critical phenomena in random graphs, random matrices, and disordered media. A possible topic for a PhD project is to study scaling properties of spectra associated with complex networks. This involves studying eigenvalues of adjacency matrices and Laplace matrices of random graphs of various types, including the Erdős-Rényi random graph, the configuration model, the preferential attachment model, and inhomogeneous variations of those. Mathematical techniques that will be used come from probability theory, combinatorics and functional analysis. The PhD projects will be co-supervised by Dr. Luca Avena and Dr. Rajat Hazra (Leiden University).

Stella Kapodistria (TU Eindhoven)

Stella Kapodistria performs research in the field of applied probability and stochastic operations research. One of her current research interests is in designing of optimal or near optimal online polices for decision making under uncertainty. The research is fundamental in nature, but is inspired by real-life problems arising from practical situations. A possible topic for a PhD project is the integration of learning and decision making. A normative direction of approach is to incorporate a Bayesian learning approach to the stochastic optimisation problem. However, the limitation of this approach is that it requires knowledge of the underlying stochastic model and it suffers from computational complexity issues outside of conjugate updating families. This could be overcome by considering a Bayesian optimisation algorithm for reinforcement learning. Effectively, the Bayesian optimisation framework for optimal decision making addresses the exploration-exploitation tradeoff. Another possible topic is the determination of structural properties of the optimal policy and the incorporation of such structural properties for fast and efficient online algorithms.

Michel Mandjes (University of Amsterdam)

Michel Mandjes performs research in the field of applied probability and stochastic operations research. One of his current interests is in developing techniques to infer the characteristics of the stochastic processes that feed into a network, solely based on performance measurements. A project in this direction would be in collaboration with Liron Ravner (Haifa University). Another possible topic for a PhD project concerns traffic management mechanisms (in collaboration with René Bekker from VU) for road traffic networks—here typical problems concern the stochastic modelling of travel times, route selection for models with random per-route travel times, and routing algorithms for delivery services.

Frits Spieksma (TU Eindhoven).

Frits Spieksma is interested in combinatorial optimization problems—for example routing, clustering, and scheduling problems (in particular sport scheduling)—and he studies both their theoretical properties as well as their applications. Understanding the precise solvability of such problems is the driving theme of his research. A possible topic for a PhD project is the study of allocation decisions. A prime example of such decisions are kidney exchange models, where we are studying the impact of recourse. A PhD-project in this direction would be co-supervised with Bart Smeulders (TU/e). Another possible topic is Integer Programming (IP). IP is the workhorse of combinatorial optimization. Further understanding and identifying its strengths and limitations is key, and symmetry plays a fundamental role here. A PhD-project in this direction would be co-supervised with Christopher Hojny (TU/e). Other topics, such as robust optimization applied to specific combinatorial problems or problems at the interface of combinatorial optimization and computational geometry, are possible as well. A project of the latter type would be co-supervised with Mark de Berg.

Appendix B: The NETWORKS project and research themes

Networks for communication, transportation, finance and energy form the backbone of modern society. Reliable and efficient network infrastructures are of enormous economic and social value, and their importance will only increase in the coming years. Researchers in the NETWORKS project perform research in *stochastics*, to model and understand large-scale networks (and to predict network growth and network processes) and *algorithmics*, to control and optimize networks and network processes in the best possible way. The research is of a fundamental nature: the goal is to develop new theory in the areas of stochastics and algorithms, thus proving a deeper understanding of mathematical and algorithmic techniques needed to model, control and optimize (processes on) networks.

The NETWORKS research program is organized around eight themes. These themes should not be interpreted as disjoint research lines, but rather as "views'' that stress different aspects. Some themes focus on algorithmic techniques (Approximate and exact network methods, Quantum network algorithms), others on different structures of networks (Spatial networks), on dynamic networks and network processes (Dynamics on networks, Dynamics of networks), and on specific applications (Transportation networks, Communication networks and Energy networks).

Theme 1: Approximate and exact network methods. Algorithmic problems concerning the design, optimization, and control of networks are often NP-hard, meaning that no efficient algorithms exist that solve these problems optimally on all possible instances. We study two approaches to deal with this. One is to develop approximation algorithms, which are guaranteed to compute near-optimal solutions. Another is to exploit that not all input instances are equally hard: some enjoy structural properties that can be exploited to efficiently compute an optimal solution.

Theme 2: Spatial networks. Many real-world networks are spatial: nodes have a location in space and edges are defined by physical connections or geographic proximity between the nodes. Typically, connections between nearby nodes are more abundant than connections between distant nodes, yet long-range connections play a crucial role in the behaviour that these networks exhibit. In addition, a high variability in the degrees of the nodes is observed. We study how and in which situations it is possible to exploit the geometry of the network, to obtain better solutions to network problems.

Theme 3: Quantum network algorithms. Quantum computers are based on the laws of quantum mechanics. They hold great promise as a future generation of hardware, since computing with qubits—a qubit is the quantum equivalent of a classical bit—allows for massive parallel computing. NETWORKS focuses on quantum software for networks problems. A key question is which computational problems can be solved significantly faster on quantum computers, and which are still very hard. NETWORKS collaborates with QuSoft Amsterdam, the first research centre in the world exclusively dedicated to quantum software.

Theme 4: Dynamics of networks. Networks evolve over time, in a way that is typically closely related to their functionality. The theory of random graphs is an essential mathematical tool 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 behaviour can be captured and analysed. Within NETWORKS we develop and analyse random-graph models and we investigate which models are best for which applications.

Theme 5: Dynamics on networks. Network functionality can often be described in terms of stochastic processes taking place on networks. Mathematical theory that applies to real-world networks is scarce, however, since existing theory focuses on random processes in very regular networks such as grids, while real-world networks are usually highly irregular. Within NETWORKS we investigate how the behaviour of stochastic network processes is affected by the irregular structure of the network, in particular, the presence of "hubs".

Theme 6: Transportation networks. The efficient usage of road, railway and other transportation networks poses many mathematical challenges. The challenges arise in all stages, from the design of the network, to the regulation of network traffic, and the maintenance or expansion of the network. Research within NETWORKS deals both with structure-related issues (planning and dimensioning of transportation and traffic networks) and with the operations on existing networks (routing, scheduling and other traffic management mechanisms relating to shorter time scales).

Theme 7: Communication networks. Communication networks need to be designed to consistently achieve high levels of performance and reliability, and yet be cost-effective to operate. This is highly challenging because of the variability in network traffic as well as the enormous complexity of communication networks such as the internet. We study e.g. how processes on networks (such as the spreading of viruses, fake news, etcetera) evolve and can be controlled, and how to construct and control communication networks to maximize efficiency.

Theme 8: Energy networks. The shift towards renewable energy sources such as wind and solar energy is causing a significant variability in supply to electricity networks. As a result supply and demand may no longer match at any given time, leading to serious reliability issues and loss of efficiency. Our research aims at getter a better grip on this by developing and analyzing novel mathematical models for energy networks.

Appendix C: Information about the four institutions

TU Eindhoven

The TU Eindhoven (TU/e) is a technical university with nine departments, approximately 2000 scientific staff (including PhD students) and 8000 BSc and MSc students. The Department of Mathematics and Computer Science is the largest of these departments, offering several bachelor and master programs, all of which are taught in English. The TU/e campus is in the center of Eindhoven, a lively city in the heart of the high-tech industry in the Netherlands. Including suburbs, Eindhoven has about 400,000 inhabitants, making it the fifth largest city of the Netherlands. There is no need to own a car: within Eindhoven everything is reachable by bike, and other cities in the Netherlands can be easily reached by public transport.

More information:

- General information about TU/e and the Department of Mathematics and Computer Science
- Employment conditions at TU/e
- Support for internationals

University of Amsterdam

The University of Amsterdam is the Netherlands' largest university, offering the widest range of academic programmes. At the UvA, 30,000 students, 6,000 staff members and 3,000 PhD candidates study and work in a diverse range of fields, connected by a culture of curiosity. The UvA counts over a hundred different nationalities. The UvA is consistently ranked among the world's best universities in global rankings. It is a top 100 university in the THE Rankings, QS Rankings and Leiden Ranking. The UvA is also member of the League of European Research Universities and Universitas 21. The UvA is working to consolidate its teaching and research activities within four campuses including Amsterdam Science Park. Amsterdam Science Park is a centre for research innovation and entrepreneurship. Major research institutions are located here alongside about 120 companies and spin-offs.

- General information about UvA and the Faculty of Science
- Working at UvA
- The UvA in Amsterdam

Leiden University

Leiden University was founded in 1575. It is one of Europe's leading international research universities, with currently 31,000 students and 7100 staff, spread over locations in Leiden and The Hague. The university hosts 3000 international and exchange students each year, and has 1000 international PhD students and 800 international academic staff. Leiden University features among the top 100 universities in international rankings. Its membership in the League of European Research Universities is of particular strategic importance. The city of Leiden has 125,000 inhabitants and is known for its

centuries-old architecture. University buildings are scattered throughout the city and students give the city a bustling and vivid atmosphere. The many important scientific discoveries made at the university over the past centuries have led to the motto: 'Leiden: City of Discoveries'.

- [About Leiden university](#)
- [Working at Leiden University](#)

Centrum Wiskunde & Informatica (CWI)
CWI is the Dutch national research institute for mathematics and computer science. Next to other research topics, main research themes are artificial intelligence, computation, data, networks, software, and quantum. By creating a synergy between mathematics and computer science, CWI pursues fundamental and long-term innovation and has been the birthplace of numerous pioneering breakthroughs. Our strength is discovering and developing new ideas that benefit society. Located at the Science Park of the vibrant city of Amsterdam, CWI is surrounded by many inspiring people and organizations. CWI plays a key role in academic networks, and maintains excellent relations with universities and industry. At CWI over 175 researchers conduct pioneering research and share their acquired knowledge with society. Over 30 researchers are also employed as professors at universities.

More information:

- [General information about CWI](#)
- [Working at CWI](#)