Lecture Notes in Computer Science 11639

More information about this series at http://www.springer.com/series/7407

Keren Censor-Hillel · Michele Flammini (Eds.)

Structural Information and Communication Complexity

26th International Colloquium, SIROCCO 2019
L'Aquila, Italy, July 1–4, 2019
Proceedings

Springer

Editors
Keren Censor-Hillel
Technion
Haifa, Israel

Michele Flammini
University of L'Aquila
L'Aquila, Italy

ISSN 0302-9743 ISSN 1611-3349 (electronic)
Lecture Notes in Computer Science
ISBN 978-3-030-24921-2 ISBN 978-3-030-24922-9 (eBook)
https://doi.org/10.1007/978-3-030-24922-9

LNCS Sublibrary: SL1 – Theoretical Computer Science and General Issues

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

This volume contains the papers presented at SIROCCO 2019: the 26th International Colloquium on Structural Information and Communication Complexity held during July 1–4, 2019, in L'Aquila. SIROCCO is devoted to the study of the interplay between structural knowledge, communication, and computing in decentralized systems of multiple communicating entities. Special emphasis is given to innovative approaches leading to better understanding of the relationship between computing and communication. SIROCCO has a tradition of interesting and productive scientific meetings in a relaxed and pleasant atmosphere, attracting leading researchers in a variety of fields in which communication and knowledge play a significant role. This year, SIROCCO was held in L'Aquila, a beautiful historical city on a mountain side, 100 km away from Rome.

For SIROCCO 2019 we received 39 submissions. Each submission was reviewed by three reviewers, either Program Committee (PC) members or external reviewers. The PC decided to accept 19 papers and to invite nine papers to be presented as brief announcements. The committee decided to give the SIROCCO 2019 Best Student Paper Award to Sebastian Brandt, Manuela Fischer and Jara Uitto, for their paper "Breaking the Linear-Memory Barrier in MPC: Fast MIS on Trees with Strongly Sublinear Memory."

Selected papers will also be invited to appear in a special issue of the *Theoretical Computer Science journal*, devoted to SIROCCO 2019.

In addition to the contributed talks, the conference program included invited talks by Susanne Albers, Pierre Fraigniaud, and Merav Parter, and a featured talk by Paola Flocchini – recipient of the 2019 Prize for Innovation in Distributed Computing. Before the start of the technical program, a 6-hour mini-course by Roger Watthenofer on blockchain was offered to the participants.

We would like to thank all of the authors for their high-quality submissions and all of the speakers for their excellent talks. We are grateful to the PC and all external reviewers for their efforts in putting together a great conference program, to the Steering Committee, chaired by Andrzej Pelc, for their help and support, and to everyone who was involved in the local organization. The EasyChair system was used to handle the submission of papers, manage the review process, and generate these proceedings.

July 2019

Keren Censor-Hillel
Michele Flammini

Organization

Program Committee

Dan Alistarh	IST, Austria
James Aspnes	Yale, USA
Alkida Balliu	Aalto University, Finland
Vittorio Bilò	University of Salento, Italy
Lelia Blin	LIP6, France
Ioannis Caragiannis	University of Patras, Greece
Keren Censor-Hillel	Technion, Israel
Michele Flammini	GSSI and University of L'Aquila, Italy
Luisa Gargano	Università di Salerno, Italy
Chryssis Georgiou	University of Cyprus, Cyprus
Magnus Halldorsson	Reykjavik University, Iceland
Tomasz Jurdzinski	University of Wroclaw, Poland
Fabian Kuhn	University of Freiburg, Germany
Toshimitsu Masuzawa	Osaka University, Japan
Alessia Milani	LaBRI, University of Bordeaux 1, France
Ivan Rapaport	Universidad de Chile, Chile
Dror Rawitz	Bar-Ilan University, Israel
Mordechai Shalom	Tel-Hai College, Israel
Jennifer Welch	Texas A&M University, USA
Prudence W. H. Wong	University of Liverpool, UK
Yukiko Yamauchi	Kyushu University, Japan

Steering Committee

Shantanu Das	Aix-Marseille University, France
Rastislav Kralovic	Comenius University, Slovakia
Zvi Lotker	Ben-Gurion University, Israel
Boaz Patt-Shamir	Tel Aviv University, Israel
Andrzej Pelc	University of Québec, Canada
Nicola Santoro	Carleton University, Canada
Sebastien Tixeuil	University of Paris 6, France
Jukka Suomela	Aalto University, Finland

Organizing Committee

Guido Proietti	University of L'Aquila, Italy
Gianlorenzo D'Angelo	GSSI, Italy
Mattia D'Emidio	University of L'Aquila, Italy
Michele Flammini	GSSI and University of L'Aquila, Italy

Luciano Gualà	University of Rome Tor Vergata, Italy
Ludovico Iovino	GSSI, Italy
Cosimo Vinci	University of L'Aquila, Italy

Additional Reviewers

Brandt, Sebastian
Böhnlein, Toni
Chalopin, Jérémie
Cordasco, Gennaro
Devismes, Stéphane
Dubois, Swan
Feuilloley, Laurent
Fraigniaud, Pierre
Gelles, Ran
Helgason, Sigurur
Hirvonen, Juho
Karakostas, George
Kim, Yonghwan
Klasing, Ralf
Korhonen, Janne H.
Kranakis, Evangelos
Kuszner, Lukasz
Labourel, Arnaud
Lotker, Zvi
Marcoullis, Ioannis
Markou, Euripides
Montealegre, Pedro
Nowicki, Krzysztof
Ooshita, Fukuhito
Pajak, Dominik
Rabie, Mikaël
Rescigno, Adele
Rybicki, Joel
Sudo, Yuichi
Tonoyan, Tigran
Uitto, Jara
Vaccaro, Ugo
Viglietta, Giovanni
Voudouris, Alexandros
Zaks, Shmuel

Laudatio: 2019 SIROCCO Prize for Innovation in Distributed Computing

It is a pleasure to award the 2019 SIROCCO Prize for Innovation in Distributed Computing to Paola Flocchini. Paola is a well-known member of the distributed computing community and her work is very closely related to SIROCCO's area of interest, i.e., the relationships between information and efficiency in decentralized computing. Most of her research can be divided into two parts. The first is the analysis of a property of labeled graphs called "sense of direction". This property which is a generalization of the orientation of rings or grids to arbitrary graphs, turns out to have major impacts on complexity and computational feasibility of communication systems. Paola's first publication on this topic [1] appeared in the first edition of SIROCCO and its journal version was later published in [2]. After that introductory paper, she wrote over 20 other papers focused on sense of direction, further exploring the impact of this property in distributed computations, all published in international conferences and top level international journals, such as the SICOMP paper [3].

The core of this part of Paola Flocchini's scientific work showed the dramatic effect that sense of direction has on the communication complexity of several important distributed problems, such as broadcast, depth-first traversal, election, spanning tree construction, in several classes of graphs. Before the seminal 1994 paper, an extensive body of evidence existed on the impact that specific edge labelings have on the communication complexity of distributed problems, suggesting that these (very different) labelings shared a common property. However, despite the obvious practical importance, a formal characterization of this property did not exist. Thus, the impact of this paper has been to provide a formal definition of sense of direction, defining those properties which make it possible to reduce the communication complexity in a distributed scenario. The final outcome of this work was to make explicit the very specific relationship between three factors: the labeling, the topological structure, and the local view that an entity has of the system.

Paola's work on sense of direction attracted a lot of attention in the distributed computing community, and generated a substantial amount of follow-up, producing a great body of scientific effort on this topic, as witnessed by over 150 citations (SCOPUS) of Paola's papers related to this matter.

The second important part of Paola's work concerns the theory of computation by autonomous mobile agents, i.e., distributed systems populated by moving and computing entities, that aim at solving various tasks. She contributed to the study of such entities both in the continuous setting (robots moving on a 2D plane), and in the discrete setting (agents acting in a network). In the continuous setting, she co-created the asynchronous oblivious mobile robots model called ASYNCH, and then studied several problems in this model, such as the gathering and the arbitrary pattern formation problem. She published over 20 papers on this topic, that collected more than 650 citations (SCOPUS), witnessing again the great interest of the distributed computing community in this area. One of the first of Paola's papers on mobile robots [4] was published in SIROCCO, and one of the most influential of her papers on asynchronous robots computing was the SICOMP paper [5].

Paola's body of work on mobile agents stimulated a lot of subsequent research, contributing to the development of this field, witnessed by numerous citations, and by establishing of the Moving and Computing international workshops, that periodically gather researchers from the distributed computing community interested in mobile agents computing.

We award the 2019 SIROCCO Prize for Innovation in Distributed Computing to Paola Flocchini for her contributions to the study of sense of direction in labeled graphs and to the analysis of asynchronous systems of mobile agents.

The 2019 Award committee[1]

Shantanu Das	Aix-Marseille Université
Pierre Fraigniaud	Université Paris Diderot, CNRS
Andrzej Pelc (Chair)	Université du Québec en Outaouais
Christian Scheideler	Paderborn University
Jukka Suomela	Aalto University
Sébastien Tixeuil	Sorbonne Université

Selected Publications Related to Paola Flocchini's Contribution:

1. P. Flocchini, B. Mans, N. Santoro,
   Sense of Direction: Formal Definitions and Properties,
   Proc. 1st Colloquium on Structural Information and Communication Complexity, (SIROCCO 94), 9–33, 1994.
2. P. Flocchini, B. Mans, N. Santoro
   Sense of Direction: Definitions, Properties, and Classes,
   Networks 32(3), 165–180, 1998.
3. P. Flocchini, A. Roncato, N. Santoro,
   Sense of Direction and Backward Consistency in Advanced Distributed Systems,
   SIAM Journal on Computing 32(2), 281–306, 2003.
4. P. Flocchini, G. Prencipe, N. Santoro, P. Widmayer,
   Pattern Formation by Anonymous Robots Without Chirality,
   Proc. 8th International Colloquium on Structural Information and Communication Complexity (SIROCCO 2001), 147–162, 2001.
5. M. Cieliebak, P. Flocchini, G. Prencipe, N. Santoro,
   Distributed Computing by Mobile Robots: Gathering,
   SIAM Journal on Computing, 41(4): 829–879, 2012.

[1] We wish to thank the nominators for the nomination and for contributing heavily to this text.

Abstracts of Invited Talks

On Energy Conservation in Data Centers

Susanne Albers

Department of Computer Science, Technical University of Munich
albers@in.tum.de

Abstract. We study algorithmic problems arising in data center operations with the objective to minimize the consumed energy. Specifically, we examine two settings that dynamically rightsize the pool of active servers depending on the current demand for computing capacity.

Data centers host a large number of power-heterogeneous servers. Each server has an active state and several standby/sleep states with individual power consumption rates. The demand for computing capacity varies over time. Idle servers may be transitioned to low-power modes so as to adjust the pool of active servers. The goal is to find a state transition schedule for the servers that minimizes the total energy consumed. For this power/capacity management problem, we present two main results. First, we investigate the scenario that each server has two states, i.e. an active state and a sleep state. We show that an optimal solution, minimizing energy consumption, can be computed in polynomial time by a combinatorial algorithm. The algorithm resorts to a single-commodity min-cost flow computation. Second, we study the general scenario that each server has an active state and multiple standby/sleep states. We devise a τ-approximation algorithm that relies on a two-commodity min-cost flow computation. Here τ is the number of different server types. A data center has a large collection of machines but only a relatively small number of different server architectures. Moreover, in the optimization one can assign servers with comparable energy consumption to the same class. Technically, both of our algorithms involve non-trivial flow modification procedures.

Additionally, we address an optimization problem introduced by Lin, Wierman, Andrew and Thereska [3] that, over a time horizon, minimizes a combined objective function consisting of operating cost, modeled by a sequence of convex functions, and server switching cost. All prior work addresses a continuous setting in which the number of active servers, at any time, may take a fractional value. We investigate for the first time the discrete data-center optimization problem where the number of active servers, at any time, must be integer valued. Thereby we seek truly feasible solutions. First, we show that the offline problem can be solved in polynomial time. Our algorithm relies on a new, yet intuitive graph theoretic model of the optimization problem and performs binary search in a layered graph. Second, we study the online problem and extend the algorithm *Lazy Capacity Provisioning* (LCP) by Lin et al. [3] to the discrete setting. We prove that LCP is 3-competitive. Moreover, we show that no deterministic online algorithm can achieve a competitive ratio smaller than 3. Hence, while LCP does not attain an optimal competitiveness in the continuous setting, it does so in the discrete problem examined here.

The presentation is based on our publications [1, 2].

References

1. Albers, S.: On energy conservation in data centers. In: Proceedings of 29th ACM Symposium on Parallelism in Algorithms and Architectures (SPAA), pp. 35–44 (2017)
2. Albers, S., Quedenfeld, J.: Optimal algorithms for right-sizing data centers. In: Proceedings of 30th ACM Symposium on Parallelism in Algorithms and Architectures (SPAA), pp. 363–372 (2018)
3. Lin, M., Wierman, A., Andrew, L.L.H., Thereska, E.: Dynamic right-sizing for power-proportional data centers. IEEE/ACM Trans. Netw. **21**(5),1378–1391 (2013)

A Topological Perspective on Distributed Network Algorithms

Armando Castañeda[1], Pierre Fraigniaud[2], Ami Paz[2],
Sergio Rajsbaum[1], Matthieu Roy[3], and Corentin Travers[4]

[1] UNAM, Mexico
{armando.castaneda,rajsbaum}@im.unam.mx
[2] CNRS and Université de Paris, France
{pierref,amipaz}@irif.fr
[3] CNRS, France
roy@laas.fr
[4] CNRS and University of Bordeaux, France
travers@labri.fr

Abstract. More than two decades ago, combinatorial topology was shown to be useful for analyzing distributed fault-tolerant algorithms in shared memory systems and in message passing systems. In this work, we show that combinatorial topology can also be useful for analyzing distributed algorithms in networks of arbitrary structure. To illustrate this, we analyze consensus, set-agreement, and approximate agreement in networks, and derive lower bounds for these problems under classical computational settings, such as the LOCAL model and dynamic networks.

On Sense of Direction and Mobile Agents

Paola Flocchini

University of Ottawa, Canada
paola.flocchini@uottawa.ca

Abstract. An edge-labeled graph is said to have *Sense of Direction* if the labeling satisfies a particular set of global consistency properties. When the graph represents a system of communicating entities, the presence of sense of direction has been shown to have a strong impact on computability and complexity.

Since its introduction, sense of direction has been investigated from various view points, revealing interesting graph theoretical properties and providing useful tools for the design of efficient distributed algorithms; furthermore, its presence allows to solve some otherwise unsolvable problems.

Far from being exhausted, the study of sense of direction and other consistency properties of edge-labeled graphs is still filled with interesting questions, open problems, and important new research directions.

In this paper, we revisit sense of direction reviewing the main results in the context of message passing point-to-point models, showing its impact in the more recent mobile agents models, and indicating directions for future study.

This work was supported in part by an NSERC Discovery Grant and by Dr. Flocchini's University Research Chair.

Secure Distributed Algorithms

Merav Parter

Weizmann Institute, Rehovot, Israel
merav.parter@weizmann.ac.il

Abstract. In the area of distributed graph algorithms a number of network's entities with local views solve some computational task by exchanging messages with their neighbors. Quite unfortunately, an inherent property of most existing distributed algorithms is that throughout the course of their execution, the nodes get to learn not only their own output but rather learn quite a lot on the inputs or outputs of many other entities. This leakage of information might be a major obstacle in settings where the output (or input) of network's individual is a private information (e.g., networks of selfish agents, decentralized digital currency such as Bitcoin).

While being quite an unfamiliar notion in the classical distributed setting, the notion of secure multi-party computation (MPC) is one of the main themes in the Cryptographic community. The existing secure MPC protocols do not quite fit the framework of classical distributed models in which only messages of bounded size are sent on graph edges in each round. In [1, 2], we present a new framework for *secure distributed graph algorithms* and provide the first *general compiler* that takes any "natural" non-secure distributed algorithm that runs in r rounds, and turns it into a secure algorithm that runs in $\widetilde{O}(r \cdot D \cdot \mathsf{poly}(\Delta))$ rounds[1] where Δ is the maximum degree in the graph and D is its diameter. A "natural" distributed algorithm is one where the local computation at each node can be performed in polynomial time. An interesting advantage of our approach is that it allows one to decouple between the price of locality and the price of *security* of a given graph function f. The security of the compiled algorithm is information-theoretic but holds only against a semi-honest adversary that controls a single node in the network.

The main technical part of our compiler is based on a new cycle cover theorem: We show that the edges of every bridgeless graph G of diameter D can be covered by a collection of cycles such that each cycle is of length $\widetilde{O}(D)$ and each edge of the graph G appears in $\widetilde{O}(1)$ many cycles. This is (existentially) optimal upto polylogarithmic terms.

In the second part of the talk, I will also discuss the notion of optimality in secure computation [3]. We will see how to adapt the existentially nearly optimal compiler into one that is nearly *optimal* (w.r.t. running time) for the given input graph G.

Keywords: CONGEST model · Cycle cover · Secure computation

Supported in part by grants from the Israel Science Foundation (no. 2084/18).

[1] The $\widetilde{O}(\cdot)$ notation hides poly-logarithmic terms in the number of vertices n.

References

1. Parter, M., Yogev, E.: Low congestion cycle covers and their applications. In: Proceedings of the Thirtieth Annual ACM-SIAM Symposium on Discrete Algorithms, SODA, pp. 1673–1692 (2019)
2. Parter, M., Yogev, E.: Distributed algorithms made secure: a graph theoretic approach. In: Proceedings of the Thirtieth Annual ACM-SIAM Symposium on Discrete Algorithms, SODA, pp. 1693–1710 (2019)
3. Parter, M., Yogev, E.: Secure distributed computing made optimal. In: Proceedings of the 2019 ACM Symposium on Principles of Distributed Computing, PODC (2019)

Contents

Brief Announcements