

# Lecture Notes in Computer Science

579

Edited by G. Goos and J. Hartmanis

Advisory Board: W. Brauer D. Gries J. Stoer



S. Toueg P. G. Spirakis L. Kirousis (Eds.)

# Distributed Algorithms

5th International Workshop, WDAG '91

Delphi, Greece, October 7–9, 1991

Proceedings

**Springer-Verlag**

Berlin Heidelberg New York

London Paris Tokyo

Hong Kong Barcelona

Budapest

Series Editors

Gerhard Goos  
Universität Karlsruhe  
Postfach 69 80  
Vincenz-Priessnitz-Straße 1  
W-7500 Karlsruhe, FRG

Juris Hartmanis  
Department of Computer Science  
Cornell University  
5148 Upson Hall  
Ithaca, NY 14853, USA

Volume Editors

Sam Toueg  
Dept. of Computer Science, Cornell University  
4106 Upson Hall, Ithaca, NY 14853, USA

Paul G. Spirakis  
Dept. of Computer Science and Engineering  
and Computer Technology Institute, Patras University  
P. O. Box 1122, 26110 Patras, Greece

Lefteris Kirousis  
Dept. of Computer Engineering and Informatics  
Patras University  
P. O. Box 1045, 26110 Patras, Greece

CR Subject Classification (1991): F.1, D.1.3, F.2.2, C.2.2, C.2.4, D.4.4–5

ISBN 3-540-55236-7 Springer-Verlag Berlin Heidelberg New York  
ISBN 0-387-55236-7 Springer-Verlag New York Berlin Heidelberg

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer-Verlag. Violations are liable for prosecution under the German Copyright Law.

© Springer-Verlag Berlin Heidelberg 1992  
Printed in Germany

Typesetting: Camera ready by author  
Printing and binding: Druckhaus Beltz, Hemsbach/Bergstr.  
45/3140-543210 - Printed on acid-free paper

# Preface

The fifth International Workshop on Distributed Algorithms (WDAG 91) took place October 7–9, 1991, in Delphi (where the oracle comes from). The workshop covers the area of distributed algorithms and is intended to provide a forum for researchers and other parties interested in distributed algorithms, communication networks and decentralized systems. The aim is to present recent research results, explore directions for future research and identify common fundamental techniques that serve as building blocks in many distributed algorithms.

The workshop followed four successful workshops in Ottawa (1985), Amsterdam (1987), Nice (1989) and Bari (1990). Since 1987 The WDAG proceedings have been published by Springer-Verlag in the Lecture Notes in Computer Science series.

The 23 papers were selected by the Program Committee from about fifty extended abstracts submitted within the announced deadline in response to a call for papers. The selection was based—first and foremost—on perceived originality and quality, but also on thematic appropriateness and topical balance. The careful screening by the Program Committee may be compared to the standard refereeing process.

It is expected that the authors will prepare extended versions of their papers to be submitted for refereed publication in one of the scientific journals. The Program Committee wishes to thank all who submitted papers for consideration.

The Program Committee consisted of:

Y. Afek (Hebrew U.)	P. Spirakis (co-chairman) (Patras U.)
V. Hadzilacos (U. Toronto)	M. Yung (IBM Yorktown)
J. Van Leeuwen (Utrecht U.)	C. Dwork (IBM Almaden)
N. Santoro (Cartelon U.)	S. Kutten (IBM Yorktown)
P. M. B. Vitányi (CWI and U. Amsterdam)	B. Sanders (ETH Zürich)
D. Dolev (Hebrew U. and IBM Almaden)	S. Toueg (co-chairman) (Cornell U.)
A. Itai (Technion U.)	S. Zaks (Technion U.)
F. Mattern (U. Kaiserslautern)	

WDAG 91 was organized by the Computer Technology Institute (CTI) of Patras University, Greece and the local Arrangements Chair was Prof. L. Kirousis (Patras U.)

WDAG 91 was followed by an ALCOM activity on Distributed Computing. ALCOM stands for the project Algorithms and Complexity of ESPRIT Basic Research Action 3075 of the European Communities. The ALCOM activity took place in Delphi during the afternoon of October 9 and S. Kutten (invited speaker, IBM Yorktown) lectured on broadcasting in dynamic networks.

We wish to express our gratitude to all the members of the Program Committee for their cooperation. We would also like to thank all the referees who assisted them. The list of referees is as complete as we can and we apologise for any omissions or errors.

We gratefully acknowledge the institutions which financially supported this Conference: CTI, Technical Chamber of Greece, ALCOM Project of ESPRIT.

Last but not least, we wish to express our gratitude to the members of the Organizing Committee and to the CTI researchers who helped in many things: L. Kirousis, P. Spirakis, L. Gourdoupi, Y. Garofalakis, C. Bouras, Ph. Tsigas, V. Kapoulas. Through their dedication and effort they made the conference possible. Many thanks are due to the people of the Cultural Center of Delphi who hosted the workshop. We also thank Ms Fotini Anastasopoulou of Albatros Travel for her excellent and highly professional job in handling the organization of the conference.

Patras, December 1991

Sam Toueg  
Paul Spirakis  
Lefteris Kirousis

## List of Referees

Afek, Y.  
Attiya, H.  
Ben-David, S.  
Biran, O.  
Burns, J.  
Chandra, T.  
Cohen, R.  
Dolev, D.  
Dwork. C.  
Francet, N.  
Gopal, A.  
Hadzilacos, V.  
Heuberger, P.

Israeli, A.  
Itai, A.  
Katz, S.  
Kranakis, E.  
Kutten, S.  
Lalis, S.  
Leeuwen, J. Van  
Makowski, J.  
Malka, Y.  
Mattern, F.  
Merritt, M.  
Moran, S.  
Papatriantafillou, M.

Reiter, M.  
Sanders, B.  
Santoro, N.  
Spirakis, P.  
Tampakas, B.  
Taubenfeld, G.  
Toueg, S.  
Tsigas, Ph.  
Vitányi, P. M. B.  
Waarts, O.  
Yadin I.  
Yung, M.  
Zaks, S.

# Table Of Contents

On the Limitations of the Global Time Assumption in Distributed Systems <i>U. Abraham, S. Ben-David and S. Moran</i> .....	1
Causal Memory <i>M. Ahamad, J. E. Burns, P. W. Hutto and G. Neiger</i> .....	9
More on the Power of Random Walks: Uniform Self-Stabilizing Randomized Algorithms <i>E. Anagnostou and R. El-Yaniv</i> .....	31
Pseudo Read-Modify-Write Operations: Bounded Wait-Free Implementations <i>J. H. Anderson and B. Großelj</i> .....	52
Maintaining Digital Clocks in Step <i>A. Arora, S. Dolev and M. Gouda</i> .....	71
Implementing FIFO Queues and Stacks <i>H. Attiya</i> .....	80
Optimal Amortized Distributed Consensus <i>A. Bar-Noy, X. Deng, J. A. Garay and T. Kameda</i> .....	95
Optimally Simulating Crash Failures in a Byzantine Environment <i>R. Bazzi and G. Neiger</i> .....	108
Efficient Distributed Consensus with $n = (3 + \epsilon)t$ Processors <i>P. Berman and J. A. Garay</i> .....	129
Randomized Consensus in Expected $O(n^2 \log n)$ Operations <i>G. Bracha and O. Rachman</i> .....	143
Using Adaptive Timeouts to Achieve At-Most-Once Message Delivery <i>S. Chaudhuri, B. A. Coan and J. L. Welch</i> .....	151
Uniform Dynamic Self-Stabilizing Leader Election <i>S. Dolev, A. Israeli and S. Moran</i> .....	167
The Quickest Path Problem in Distributed Computing Systems <i>Y-C Hung and G-H Chen</i> .....	181
The Communication Complexity of the Two-List Problem <i>A. Itai</i> .....	193
Distributed Algorithms for Updating Shortest Paths <i>G. F. Italiano</i> .....	200
Minimal Shared Information for Concurrent Reading and Writing <i>P. Jayanti, A. Sethi and E. L. Lloyd</i> .....	212
Reading Many Variables in One Atomic Operation: Solutions with Linear or Sublinear Complexity <i>L. M. Kirousis, P. Spirakis and Ph. Tsigas</i> .....	229
Analysis of Distributed Algorithms Based on Recurrence Relations <i>Y. Malka and S. Rajsbaum</i> .....	242

Detection of Global State Predicates	
<i>K. Marzullo and G. Neiger</i> .....	254
Using Consistent Subcuts for Detecting Stable Properties	
<i>K. Marzullo and L. Sabel</i> .....	273
Atomic $m$ -registers Operations	
<i>M. Merritt and Taubenfeld</i> .....	289
A Robust Distributed Mutual Exclusion Algorithm	
<i>S. Rangarajan and S. K. Tripathi</i> .....	295
Message Delaying Synchronizers	
<i>L. Shabtay and A. Segall</i> .....	309
<b>Author Index</b> .....	<b>319</b>