

Guang Xu

In-Network Processing Algorithms for Cooperative Networks

Band 8

Dissertationen aus dem
Arbeitsbereich Nachrichtentechnik
der Universität Bremen
Prof. Dr.-Ing. Armin Dekorsy



In-Network Processing Algorithms for Cooperative Networks

Dissertation

zur Erlangung des akademischen Grades

Doktor der Ingenieurwissenschaften (Dr.-Ing.)

vorgelegt dem Fachbereich 1 (Physik/Elektrotechnik)

der Universität Bremen

von

M.Sc. Guang Xu

Tag des öffentlichen Kolloquiums:	31. Januar 2020
Gutachter der Dissertation:	Prof. Dr.-Ing. Armin Dekorsy Prof. Dr. rer. nat. Jörg Fliege
Weitere Prüfer:	Prof. Dr.-Ing. Alberto Garcia-Ortiz Prof. Dr.-Ing. Karl-Ludwig Krieger



Bremen, February 17, 2020

Dissertationen aus dem Arbeitsbereich Nachrichtentechnik der
Universität Bremen

Band 8

Guang Xu

**In-Network Processing Algorithms for
Cooperative Networks**

D 46 (Diss. Universität Bremen)

Shaker Verlag
Düren 2020

Bibliographic information published by the Deutsche Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

Zugl.: Bremen, Univ., Diss., 2020

Copyright Shaker Verlag 2020

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publishers.

Printed in Germany.

ISBN 978-3-8440-7270-9

ISSN 2366-276X

Shaker Verlag GmbH • Am Langen Graben 15a • 52353 Düren

Phone: 0049/2421/99011-0 • Telefax: 0049/2421/99011-9

Internet: www.shaker.de • e-mail: info@shaker.de

Preface

This thesis is dedicated to all my research on the topic of distributed signal processing in cooperative communications applications. All the works described and discussed in this thesis were carried out when I worked as a scientific researcher ("Wissenschaftlicher Mitarbeiter") in the department of Communications Engineering, University of Bremen, between February 2013 and December 2017.

First of all, a huge thank you I would like to give my supervisor Prof. Dr.-Ing. Armin Dekorsy for all along patient guidance, helpful advices and fruitful discussions during all phases of my PhD life. I would also like to give a big thank you to Prof. Dr. rer. nat. Jörg Fliege from University Southampton, for being my second thesis assessor ("Gutachter") and for your interest to my thesis and your precious time. I am also really appreciate that both Prof. Dr.-Ing. Alberto Garcia-Ortiz and Prof. Dr.-Ing. Karl-Ludwig Krieger agreed to be the examiners ("Prüfer") of the debate for my thesis.

I am deeply grateful to Dr.-Ing. Henning Paul, for countless advices and guidance to my research work and my thesis. I would like to express my gratitude to Dr.-Ing. Dirk Wübben, for many meaningful discussions and great help to my PhD life. I also would like to thank Dr.-Ing. Carsten Bockelmann, for sharing a lot of precious knowledge with me and helpful advices on my work.

I wish to thank my colleagues MSc. Shengdi Wang and Dipl.-Ing. Ban-Sok Shen, as members of the research group of distributed processing, we had a lot of great discussions and creative conversations. I also would like to thank Dr.-Ing. Henning Schepker and M.Sc. Ahmed Moheeb Emara, as officemates, we had pleasant atmosphere and shared great time in our office. Especially, I want to thank our secretary, Ms. Eva Preuss, and technician, Dipl.-Ing. Anouar Chahbouni, for their kind and endless help for many practical issues. Last but not least I would like to thank Dr.-Ing. Florian Lenkeit, Dr.-Ing. Fabian Monsees, Dr.-Ing. Matthias Woltering, Dr.-Ing. Tobias Schnier, MSc. Shayan Hassanpour, M.Sc. Johannes Demel for the great and unforgettable

time we spent together inside and outside our department.

Finally, I would like to give my deepest thank to my whole family, for the unlimited support from my wife, for the constant encouragement from my parents, and for the endless trust from my relatives and my friends.

February 17, 2020

Guang Xu

Contents

Preface	III
1 Introduction	1
1.1 Motivation	1
1.2 Goal of This Thesis	3
1.3 Main Contributions	4
1.4 Structure and Overview	7
1.5 Nomenclature	8
2 In-Network Processing	11
2.1 Chapter Overview	11
2.2 About In-Network Processing	11
2.2.1 Distributed Consensus-based Joint Estimation	14
2.2.2 Distributed Joint Precoding	15
2.2.3 Performance Indicators for INP Algorithms	16
2.3 Graph Preliminaries on Cooperative Networks	17
2.4 Constrained Optimization Problem for INP	21
2.5 Chapter Summary	25
3 INP for Distributed Consensus-based Joint Estimation	27
3.1 Chapter Overview	27
3.1.1 Main Contributions of this Chapter	27
3.1.2 Chapter Structure	28
3.2 System Model	29
3.3 Baseline and Benchmark for Distributed Consensus-based Joint Estimation	33
3.3.1 Local Linear Estimation	33
3.3.2 Central Linear Estimation	35
3.4 Distributed Consensus-based Joint Estimation Algorithms	39

3.4.1	ADMM based Distributed Algorithm for Consensus-based Joint Estimation	42
3.4.2	ALM based Distributed Algorithms for Consensus-based Joint Estimation	58
3.4.3	Virtual Clustering for Distributed Consensus-based Joint Estimation	67
3.4.4	Relaxation Methods for Distributed Consensus-based Joint Estimation	76
3.4.5	Consensus-achieving Filtering for Distributed Consensus-based Joint Estimation	86
3.5	Evaluation of INP Algorithms for Distributed Multi-User Detection in Cooperative SCs Networks	95
3.5.1	Scenario and Simulation Setup	96
3.5.2	Numerical Performance	98
3.6	Chapter Summary	102
4	INP for Distributed Joint Precoding	105
4.1	Chapter Overview	105
4.1.1	Main Contributions of this Chapter	105
4.1.2	Chapter Structure	107
4.2	System Model	108
4.3	Linear Precoder for Joint Transmission	111
4.3.1	Linear Zero-Forcing Precoding	114
4.3.2	Linear Minimum Mean Square Error Precoding	115
4.4	Distributed Joint Precoding Algorithms	118
4.4.1	Distributed Precoding on Precoding Matrices under Sum Power Constraint	121
4.4.2	Distributed Precoding on Transmit Signals under Sum Power Constraint	140
4.4.3	Distributed Precoding on Precoding Matrix under Per Node Power Constraint	148
4.4.4	Distributed Precoding on Precoding Matrices with Imperfect Channel State Information	156
4.5	Evaluation of INP Algorithms for Distributed Joint Transmission in Cooperative SC Networks	165
4.5.1	Scenario and Simulation Setup	166
4.5.2	Numerical Performance	168
4.6	Chapter Summary	173
5	Summary	177
A	Floating-point Operations Counting	183

B	Convergence Proof of the ALCE Algorithm	189
C	Convergence Proof of the PALCE Algorithm	197
D	Derivation of MMSE precoding under SPC	203
E	Convergence Analysis of the TSJ-DiP Algorithm	207
F	Convergence Analysis of the PR-DiP Algorithm	211
G	Derivations Related to DiP-PM-PNPC Algorithms	215
	Acronyms	219
	List of Symbols	223
	Bibliography	225
	Index	239