

# COST

Domain Committee "Information & Communication Technologies"

## COST Action IC1104

Start Date 26.04.2012

*Title: Random Network Coding and Designs over  $GF(q)$*

## MONITORING PROGRESS REPORT

**Reporting Period:** from 1<sup>st</sup> May 2012 to 30<sup>th</sup> April 2013

This Report is presented to the relevant Domain Committee.  
It contains three parts:

- I. Management Report*** prepared by the COST Office/Grant Holder
- II. Scientific Report*** prepared by the Chair of the Management Committee of the Action
- III. Previous versions of the Scientific Report;*** i.e., part II of past reporting periods

The report is a "cumulative" report, i.e. it is updated annually and covers the entire period of the Action.

Confidentiality: the documents will be made available to the public via the COST Action web page except for chapter *II.D. Self evaluation*.

**Executive summary:** Random Network Coding has emerged as one of the most important topics in contemporary Information Theory and Technology. As the contribution of European Countries to this field of interest has been more on the modest side during most recent years, a COST Action was thought to be the right measure to vitalize current European research in this discipline. For this purpose, COST Action IC1104 was granted at the end of 2011, and its Kick-Off meeting took place in Brussels in April 2012. Since then, under the umbrella of this Action, a number of activities have been organized, and a vast number of technical results have been achieved. In light of the Action's current number of participating countries and its significant technical success, all members are confidently entering the Action's second year.

# I. Management Report



## I.A. COST Action Fact Sheet

- **COST Action** IC1104 - Random Network Coding and Designs over  $GF(q)$
- **Domain** Information and Communication Technologies (ICT)

- **Action details:**

**CSO Approval:** 01.12.2011

**End date:** 25.04.2016

**Entry into force:** 18.01.2012

**Extension:** n/a

- **Objectives**

Random network coding emerged through an award-winning paper by R. Koetter and F. Kschischang in 2008 and has since then opened a major research area in communication technology with widespread applications for communication networks like the internet, wireless communication systems, and cloud computing. It allows transmitting information through a network by disregarding any of its topological features. As in traditional algebraic coding theory, two main research directions in random network coding are

- Existence and construction of good and optimal network codes,
- Efficient encoding and decoding schemes for a given network code.

Restriction to the so-called Grassmannian codes has proven to be advantageous and leads to the theory of designs over  $GF(q)$ . Worldwide, there exists a larger number of workgroups focusing on this topic, which includes several groups located in Europe. This COST Action will set up a European research network and establish network coding as a European core area in communication technology. Its aim is to bring together experts from pure and applied mathematics, computer science, and electrical engineering, who are working in the areas of discrete mathematics, coding theory, information theory, and related fields.

- **Parties:** *list of countries and date of acceptance*

Austria 13/11/2012	Germany 13/03/2012	Portugal 20/06/2012
Belgium 05/07/2012	Greece 13/03/2012	Serbia 02/03/2012
Bulgaria 21/03/2012	Hungary 19/11/2012	Slovakia 29/11/2012
Croatia 20/12/2011	Ireland 16/01/2012	Slovenia 23/06/2012
Denmark 02/04/2012	Israel 27/12/2011	Spain 16/02/2012
Estonia 19/11/2012	Italy 05/04/2012	Switzerland 24/01/2012
Finland 03/01/2012	Netherlands 20/11/2012	Turkey 20/04/2012
France 07/03/2012	Norway 19/03/2012	United Kingdom 01/03/2012

- **Intentions to accept:** We are in the process of accepting the application of Dr. Wei Xiang from the Southern Queensland, Australia, as member of this Action. This acceptance is based on a unanimous vote within the Management Committee Meeting in Bergen, Norway, on 19<sup>th</sup> of April 2013.

- **Other participants:** none

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- **Action Web site:** <http://www.network-coding.eu/>

- **Grant Holder Representative:** Dr Marcus Greferath, marcus.greferath@ucd.ie

**Working Groups**

**WG 1: Bounds on the Size of Network Codes**

Chairs: Tuvi Etzion, Joachim Rosenthal

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Joan-Josep Climent	Department of Statistics and Operations Research University of Alicante, Spain
Andreas-Stephan Elsenhans	Institute for Mathematics University of Bayreuth, Germany
Tuvi Etzion	Computer Science Department Technion, Israel
Szabolcs Levente Fancsali	Institute of Mathematics Eötvös Loránd University, Hungary
Thomas Feulner	Institute for Mathematics University of Bayreuth, Germany
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Petteri Kaski	Department of Information and Computer Science Aalto University, Finland
Michael Kiermaier	Institute for Mathematics University of Bayreuth, Germany
Axel Kohnert	Institute for Mathematics University of Bayreuth, Germany
Vedran Krcadinac	Department of Mathematics, Faculty of Science University of Zagreb, Croatia
Sascha Kurz	Institute for Mathematics University of Bayreuth, Germany

Ivan Landjev	Department of Informatics New Bulgarian University, Bulgaria
Anamari Nakic	Faculty of Electrical Engineering and Computing University of Zagreb, Croatia
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Ferruh Özbudak	Institute of Applied Mathematics Middle East Technical University, Turkey
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Antonia Wachter-Zeh	Institute of Communications Engineering Ulm University, Germany
Alfred Wassermann	Institute for Mathematics University of Bayreuth, Germany
Alexander Zeh	Institute of Communications Engineering Ulm University, Germany

## **WG 2: Development of Encoding and Decoding Schemes, Practical Aspects of Network Coding**

Chair: Ángeles Vázquez-Castro

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Mercè Villanueva	Information and Communications Engineering Dpt. Autonomous University of Barcelona, Spain
Dejan Vukobratovic	Department of Power, Electronics and Communication Engineering, University of Novi Sad, Serbia

### WG 3: Cryptographic Aspects of Network Codes

**Chair:** Simon Blackburn

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### WG 4: Construction of Network Codes and Grassmannian Codes

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## WG 5: Foundational Aspects, Algebraic Methods in Random Network Coding, Distributed Storage

**Chair:** Axel Kohnert

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## I.B. Management Committee member list

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## I.C. Overview activities and expenditure

### 2012-2013 Budget

**Total Action Budget: €113000**

**Remaining Action Commitment: €75684.14**

#### Meetings

Meeting Type	Date	Place	Total
Management Committee Meeting	02/11/2012 – 02/11/2012	Ascona, Switzerland	7000.00
Core Group Meeting, Working Group Meeting	04/02/2013 – 08/02/2013	Barcelona, Spain	7000.00
Management Committee Meeting, Workshop	18/04/2013 – 19/04/2013	Bergen, Norway	21500.00
Core Group Meeting, Working Group Meeting	20/06/2013 – 21/06/2013	Zürich, Switzerland	31000.00
			<b>€66500.00</b>

#### STSM

Beneficiary	Date	Place	Total
Marco Calderini (Italy)	01/15/2013 – 04/12/2013	Dublin, Ireland	2000
Michael Kiermaier (Germany)	23/02/2013 – 07/04/2013	Zagreb, Croatia	2000
Milos Stojakovic (Serbia)	28/04/2013 – 05/05/2013	Aalborg, Denmark	1300
Mladen Kovacevic (Serbia)	25/05/2013 – 08/06/2013	Aalborg, Denmark	1850
Antonia Wachter-Zeh (Germany)	30/06/2013 – 06/07/2013	Haifa, Israel	1100
		<b>Subtotal of STSMs to date</b>	<b>8250</b>
		<b>Project budget until end of grant period</b>	<b>€10000.00</b>

#### Workshops

Title	Date	Place	Total
See above in 'Meetings': Workshops	18/04/2013 – 19/04/2013	Bergen, Norway	See above

#### Schools

Title	Date	Place	Total
First European Training School in Network Coding	04/02/2013 – 08/02/2013	Barcelona, Spain	<b>€32500.00</b>

#### Dissemination

Title	Date	Place	Total
Web developer	01/08/2012 – 31/07/2013	Dublin, Ireland	3000
Content editing and compiling of data for website	01/08/2012 – 31/07/2013	Dublin, Ireland	1000
			<b>€4000.00</b>

**Action Total: €113000.00**

## II. Scientific Report

### II.A. Innovative networking

1. During the meeting in Ascona a search which was done during the last several years to find a  $q$ - Steiner systems and thus, disprove some old conjectures, was completed. This result is a true break-through in the theory of designs over  $GF(q)$ . A paper was written by Michael Braun, Tuvit Etzion, Patric Ostergard, Alexander Vardy, and Alfred Wassermann.
2. Michael Kiermaier from Bayreuth, Germany, has visited Mario Pavcevic in a Short Term Scientific Mission. They have studied the intersection numbers of  $q$ -analogs of designs. They have obtained new results and plan to submit a paper on this topic and to present the results in the next COST workshop at Ghent, Belgium, September 18-20, 2013.
3. One of Camilla Hollanti's PhD students is working on distributed storage and storage security, so far resulting in one accepted conf. paper and one submitted journal paper (to IEEE JSAC).
4. Camilla Hollanti has been working with post-doctoral colleagues on wiretap channels and information theoretic security, resulting in 2 accepted conference papers (WCC 2013 and ISIT 2013) and one submitted journal paper (Advances in Math. of Communications).
5. For distributed storage there was a paper by Bernat Gastón, Jaume Pujol, Mercè Villanueva of title: "A realistic distributed storage system: the rack model". All 3 authors are members of WG5. The paper studies the realistic case that the data is stored in different nodes which are grouped in racks. The cost of a repair depends on the questions whether or not there is a communication inside a rack.
6. Mario Pavcevic and his student Anamari Nakic have been working on tactical decompositions of  $q$ -analogs of designs. They intend to present their results at the upcoming Working Group meeting at the University of Ghent in September 2013.

### II.B. Inter-disciplinary networking

1. The trainers of the Training School in Barcelona were carefully selected to cover all three expert groups important for this project: mathematicians, computer scientists and engineers and to show their attitude to problems, their very different techniques and way of thinking and carrying out the research. This fact led to high interest of early stage researchers of all three mentioned scientific branches to join this training school. The fact that parallel to the training school Working Group Meetings were organized ensured also the presence of senior researchers of all kinds.
2. A number of short-term scientific missions (STSM) has been undertaken in order to facilitate collaboration, particularly in the inter-disciplinary sector. Here we mention the following STSMs.
  - As mentioned above, Michael Kiermaier from Bayreuth, Germany, has visited Mario Pavcevic in a Short Term Scientific Mission. They have obtained new results and plan to submit a paper in the next COST workshop at Ghent, Belgium, September 18-20, 2013.
  - Marco Calderini, has visited Eimear Byrne from University College of Dublin in a Short Term Scientific Mission from 15th of January to 12th of April 2013.

They have studied the problem of index coding with side information. They have obtained results which they plan to submit as a paper in Ghent, too.

3. Tuvi Etzion, one of the chairs of the two groups is preparing a survey on q-analog problems in coding theory. The survey will include the state of art in the related problems, research problems, all the relevant references, and some ideas of directions to tackle some of the problems. This will at the same time be a perfect reference for inter-disciplinary work within the Action, as researchers from different fields have a resource from which to pick current research topics and problems.
4. Three groups, one in Zuerich, Switzerland, led by Joachim Rosenthal, one in Dublin, Ireland, led by Marcus Greferath, and one in Porto, Portugal, led by Paula Rocha and Raquel Pinto, are working on generalization the existing results for network codes over finite rings.

### **II.C. New networking**

- Altogether, 24 member countries have joined the Action during its first year. Among these, we list the following as late joins, meaning after the kick-off meeting in April 2013: Austria, Belgium, Estonia, Hungary, the Netherlands, Portugal, Slovenia, and Slovakia.
- The total number of individuals involved in this action is 73, among which there are 13 female researchers. Regarding early-stage researchers, the Action counts (at least) 24 on board.
- More than 4 STSMs are being carried out this year. Early-stage researchers have been vastly involved in these STSMs, as the visit Kiermaier-Pavcevic, Calderini-Byrne, and Wachter-Zeh-Etzion shows. During the recent Training School in Barcelona (02/13) the Action supported 35 trainees, among them 12 female supportees.
- Quite a few experts from non-COST countries have been involved in the action and committed themselves as experts giving lectures in the recent training school and keynotes at the recent workshop in Bergen. There is a reciprocal agreement with Australia, and on the basis of this agreement, this Action has a currently pending application by a researcher from the University of Southern Queensland (AU) that will be approved within the coming few months.
- A number of publications has been authored and submitted under the umbrella of this Action. For details see the annex. Regarding further outreach activities we refer to the website that has been created and maintained by the MC member Jens Zumbraegel.

### **II.D. Self evaluation**

**III. Previous scientific report(s)** n/a