**WORKING GROUP 5:** ***FOUNDATIONAL ASPECTS, ALGEBRAIC METHODS IN RANDOM NETWORK CODING, DISTRIBUTED STORAGE***

**Chair: Camilla Hollanti**

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**Short summary of activities, see related publications at the end of the document.**

During the past year, the working group has carried out research around the following themes resulting in more 20 peer-reviewed publications and numerous invited and contributed talks:

*Steiner systems, device-to-device communications, proximity based services, fractional repetition codes for storage, extendibility of and bounds on random network codes, regenerating distributed storage codes, locally repairable codes and matroid theory, batch codes, capacity and security of distributed storage systems, physical layer storage transmission protocols, mathematical models for realistic storage racks, erasure codes with simplex locality, wiretap codes with adjoined bounds, network coding approach to object reconciliation, constellations for physical layer coding schemes, e.g., rotated constellations and so-called Fuchsian codes.*

**Organization:**

Joint WG2&WG5 meeting in Barcelona organized by the WG leaders.

**Attendance in conferences:**

ISITA, ITW, MTNS, Bordeaux, MTNS, Castle meeting, ACA Malaga, among many others have been attended by the members.

**Schools:**

IEEE European School of Information Theory, April, Tallinn, Estonia. Many participants from the group as well as a speaker from WG5 (Hollanti). Hollanti was also speaking in the CUSO Kervaire Seminar in Number Theory in Les Diablerets organized by Elisa Gorla.

**Short term study missions:**

Barreal, Blanco, and Hollanti visited Barcelona (M.-A. Vasquez-Castro, M. Alsina) in Barcelona in January-February. Barreal, Freij, and Hollanti are visiting J. Rosenthal in Zurich in November-December. STSMs are planned to Finland by G. Robert. Vitaly Skachek did a STMS in June 2013 visiting UCD, Dublin, Ireland, and worked with Eimear Byrne.

**Grants obtained on topics related to the COST Action:**

PUT 405: "New Coding Techniques in Data Communications and Storage", Estonian Research Council, 4 years (Jan 2014 - Dec. 2017), by Vitaly Skachek, includes Faruk Gologlu as a researcher.

Academy of Finland: Fidipro – Marcus Greferath/Camilla Hollanti (1.5ME), plus two further AoF research grants on applications of algebra and number theory to distributed storage systems and security (total of 660kE). Three pending applications on storaga and security, total of 1.1ME.

**List of publications:**

Toni Ernvall, Salim El Rouayheb, Camilla Hollanti, and Vincent Poor, Capacity and security of heterogeneous distributed storage systems", IEEE Journal on Selected Areas in Communications (JSAC): Special Issue on Networking Challenges in Cloud Computing Systems and Applications, 31(12), Dec. 2013, pp. 2701{2709. Available online: http://arxiv.org/pdf/1211.0415.pdf

Toni Ernvall, Thomas Westerbäck, and Camilla Hollanti, “Constructions of optimal and almost optimal locally repairable codes" (invited paper), Global Wireless Summit, Aalborg, May2014.

Camilla Hollanti, David Karpuk, Amaro Barreal, and Hsiao-feng (Francis) Lu, “Space-time storage codes for wireless distributed storage systems" (invited paper), Global Wireless Summit, Aalborg, May 2014.

Amaro Barreal, Camilla Hollanti, David Karpuk, and Hsiao-feng (Francis) Lu, “Algebraic codes and a new transmission protocol for physical layer distributed storage systems" (invited paper), The 21th International Symposium on Mathematical Theory of Networks and Systems (MTNS 2014), Groningen, July 2014.

Toni Ernvall, Salim El Rouayheb, Camilla Hollanti, and H. Vincent Poor, “Secrecy capacity of Heterogeneous Distributed Storage Systems" (abstract for invited survey talk), International Symposium on Communications, Control and Signal Processing (ISCCSP), Athens, Greece, May 2014.

Joonas Pääkkönen, Camilla Hollanti, and Olav Tirkkonen, “Device-to-device data storage and distribution for mobile cellular systems", IEEE Globecom 2013 Workshop: International Workshop on Device-to-Device (D2D) Communication With and Without Infrastructure, December 2013, Atlanta, USA.

Toni Ernvall, Salim El Rouayheb, Camilla Hollanti, and Vincent Poor, “Capacity and security of heterogeneous distributed storage systems", 2013 IEEE International Symposium on Information Theory (ISIT), Istanbul, Turkey, July 2013.

Natalia Silberstein and Tuvi Etzion “Optimal Fractional Repetition Codes"

Braun, Michael and Etzion, Tuvi and Östergård, Patric R. J. and Vardy, Alexander and Wassermann, Alfred, “Construction of $q$-analogs of Steiner systems", WCC 2013, International Workshop on Coding and Cryptography, Bergen, Norway, 2013.

Braun, Michael and Etzion, Tuvi and Östergård, Patric R. J. and Vardy, Alexander and Wassermann, Alfred, “Existence of $q$-Analogs of Steiner Systems", arXiv 1304.1462.

Braun, Michael and Kohnert, Axel and Östergård, Patric R. J. and Wassermann, Alfred, "Large Sets of $t$-Designs over Finite Fields", Journal of Combinatorial Theory A, volume 124, 2014, 195-202.

Vitaly Skachek and Michael G. Rabbat,
"Subspace Synchronization: A Network-Coding Approach to Object Reconciliation", International Symposium on Information Theory (ISIT), June-July 2014, Honolulu, HI, USA

Margreta Kuijper, Diego Napp, “Erasure codes with simplex locality”, to appear at 21st International Symposium on Mathematical Theory of Networks and Systems as an invited paper.

Bernat Gastón, Jaume Pujol, and Mercè Villanueva: "Quasi-cyclic Relaxed Regenerating Codes", submitted to IEEE Trans. Inf. Theory. 2014.

Bernat Gastón, Jaume Pujol and Mercè Villanueva: "A Realistic Distributed Storage System that Minimizes Data Storage and Repair Bandwidth”, In Proceedings of the Data Compression Conference (DCC), Cliff Lodge, Snowbird, Utah, USA, 2013.
Preprint at http://arxiv.org/abs/1301.1549, 2013.

Natalia Silberstein, Anna Gal, “Optimal Combinatorial Batch Codes Based on Block Designs”, Designs, Codes and Cryptography, to appear.

Natalia Silberstein, “Fractional Repetition and Erasure Batch Codes” 4ICMCTA.

Cristina Martinez, “Network coding, t-designs and the representation theory of GL(n, Fq)”, joint with Alberto Besana. Presented at the Cost conference in Ghent, September
2013.

Cristina Martinez, “Modeling languages from graph networks”, joint work with A. Besana, accepted at proceedings of MDAI 2014, Tokyo.

Cristina Martinez, “Modeling languages from mobile applications”, accepted at proceedings of MDAI 2014, Tokyo.

Arsenia Chorti, Mehdi M. Molu, David Karpuk, Camilla Hollanti, Alister Burr: Strong secrecy in wireless network coding systems with M-QAM modulators. In IEEE/CIC ICCC 2014 Symposium on Privacy and Security in Commutations, 2014.

Amaro Barreal Fernández, Camilla Hollanti, Nadya Markin: Construction of fast-decodable distributed space-time codes. *Proceedings of the 4th International Castle Meeting on Coding Theory and Applications (ICMCTA), CIM Series in Mathematical Sciences, Springer-Verlag*, 2014.

Thomas Westerbäck, Toni Ernvall, Camilla Hollanti: Almost affine locally repairable codes and matroid theory. In Proceedings of 2014 IEEE Inform. Theory Workshop (ITW), 2014.

Iván Blanco Chacón, Dionís Remón, Camilla Hollanti, Montserrat Alsina: Nonuniform Fuchsian codes for noisy channels. *Journal of the Franklin Institute*, 2014.

David Karpuk, Camilla Hollanti, Amaro Barreal Fernández: Node repair for distributed storage systems over noisy and fading channels. *Proceedings of International Symposium on Information Theory and its Applications (ISITA), Melbourne*, 2014, pp. 1–5.

Hsiao-feng (Francis) Lu, Camilla Hollanti, David Karpuk, Amaro Barreal Fernández: New relay-based transmission protocols for wireless distributed storage systems. *Proceedings of International Symposium on Information Theory and its Applications (ISITA), Melbourne*, 2014, pp. 1–5.

Toni Ernvall, Thomas Westerbäck, Camilla Hollanti: Constructions of optimal and almost optimal locally repairable codes. In Proceedings of Global Wireless Summit, Aalborg, May 2014, 2014.

Camilla Hollanti, David Karpuk, Amaro Barreal Fernández, Hsiao-feng (Francis) Lu: Space-time storage codes for wireless distributed storage systems. In Proceedings of Global Wireless Summit, Aalborg, May 2014, 2014.

Amaro Barreal Fernández, Camilla Hollanti, David Karpuk, Hsiao-feng (Francis) Lu: Algebraic codes and a new physical layer transmission protocol for wireless distributed storage systems. In Pre-proceedings of the 21st International Symposium on Mathematical Theory of Networks and Systems (MTNS 2014), Groningen, July 2014, 2014.

Toni Ernvall, Salim El Rouayheb, Camilla Hollanti, H. Vincent Poor: Secrecy capacity of heterogeneous distributed storage systems (abstract for invited

survey talk). *Proceedings of the International Symposium on Communications, Control and Signal Processing (ISCCSP)*, 2014.

David Karpuk, Camilla Hollanti, Emanuele Viterbo: Probability Bounds for two-dimensional algebraic lattice codes. *International Workshop on Coding and Cryptography*, 2013, pp. 448–458.

Camilla Hollanti, Emanuele Viterbo, David Karpuk: Nonasymptotic probability bounds for fading channels exploiting Dedekind zeta functions. *0*submitted, 2013.

David Karpuk, Iván Blanco Chacón, Camilla Hollanti: Probability bounds for an eavesdropper's correct decision over a MIMO wiretap channel. *IEEE International Symposium on Information Theory*, 2013, pp. 2014–2018. BibTeX

Iván Blanco Chacón, D. Remón, Camilla Hollanti: Fuchsian codes for AWGN channels. *Proceedings of the International Workshop on Coding and Cryptography WCC 2013*, 2013, pp. 496–507. BibTeX
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Kapetanovic D., Chatzinotas S., Ottersten B., “Index Assignment for Multiple Description Repair in Distributed Storage Systems”, *International Conference on Communications, ICC 2014*, Sydney, Australia, June 2014.

Chatzinotas S., “Repairing Multiple Description Quantizers in Distributed Storage Systems”, *International Conference on Communications, ICC 2013*, Budapest, Hungary, June 2013.

M. Alsina, "Hyperbolic uniformizations throught computations on ternary quadratic forms", 203-206, proceedings of ACA (Applications of Computer Algebra), http://www.aca2013.uma.es/Proceedings.pdf).

H. Lipmaa, V. Skachek, "Linear Batch Codes", Proc. 4-th International Castle Meeting on Coding Theory and Applications, Sept. 2014, Lisbon, Portugal.