Ph.D. Research Summary

Thesis Title:

Gossip and Random Walk Techniques for Network Coding

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My research has several directions. The first is **algebraic gossip** – a local, distributed and efficient algorithm for disseminating information in a network. Algebraic gossip is a gossip algorithm that is based on random linear network coding, which is a novel approach to spread information in networks. The stopping time of algebraic gossip is known to be linear for the complete graph, but the question of determining a tight upper bound or lower bounds for general graphs was still open. We published two papers ([8, 6]) on this topic and successfully answered the above open question. Moreover, in the second paper we propose a modified version of algebraic gossip that achieves optimal stopping times for almost any topology. Our proofs use an original method that relies on queuing theory. We novelly analyze algebraic gossip via reduction to network of queues (see Figure 1 for illustration) and using the *Jackson's theorem* for open networks. We believe that this type of reduction can be used for future analysis of gossip protocols.

The second direction is related to the **multi-terminal network with side information**. In this direction we published a paper [7]. Here we considered the problem of source coding with side information in large networks with multiple receivers (see Figure 2(a) for illustration). In this case, standard coding techniques are either prohibitively complex to decode, or require source-network coding separation, resulting in sub-optimal transmission schemes. To alleviate this problem, we offer a joint network-source

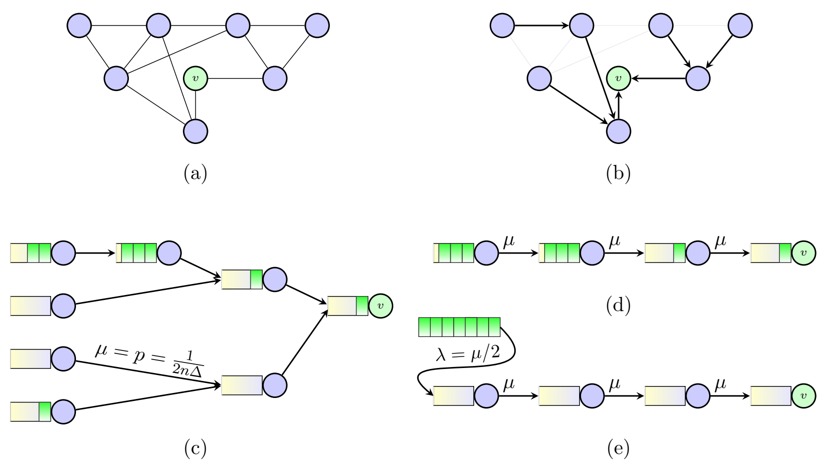


Figure 1: Reduction of AG to a system of queues.

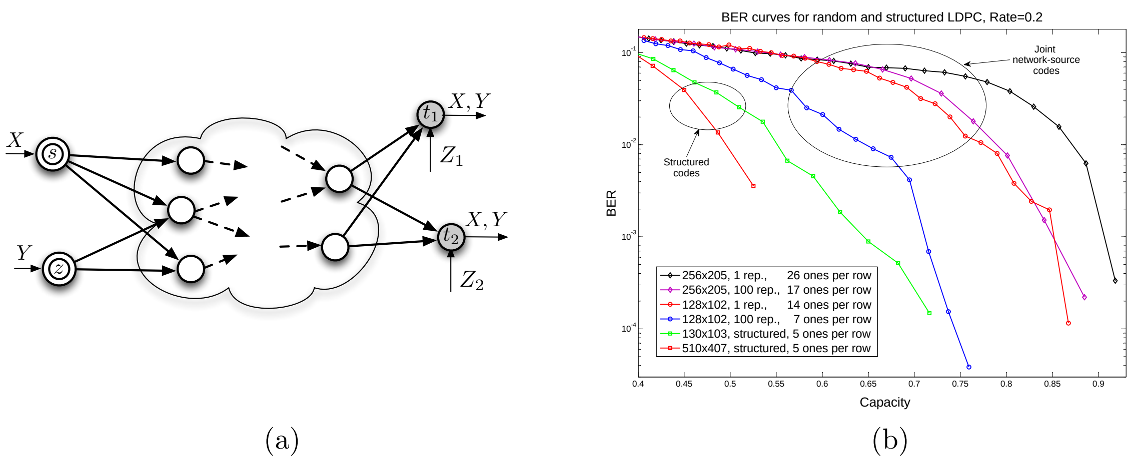
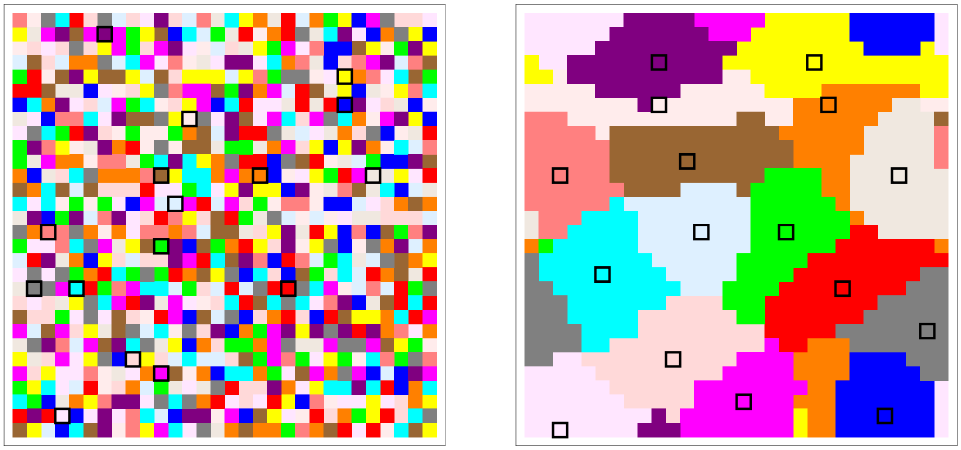


Figure 2: (a) – Terminals with side information. (b) – BERs for LDPCs created by sparsification.

coding scheme based on matrix sparsification at the code design phase, which allows the terminals to use an efficient decoding procedure (syndrome decoding using LDPC), despite the network coding throughout the network. Via a novel relation between matrix sparsification and rate-distortion theory, we give lower and upper bounds on the best achievable sparsification performance. Simulation results (see Figure 2(b) for illustration) motivate the use of the proposed scheme.

The third direction, is the **SINR and power allocation** in a setting where multiple transmitters are available to every receiver. The work led to very interesting and even surprising results and the approach that was invented is likely to be a powerful tool for solving a vast range of different problems. This work yielded a paper [1] that was submitted to the STOC 2012 conference.

A recent collaboration with an MIT Ph.D. student led to a very interesting research on **self-adjusting networks**, i.e., networks that use local-distributed mechanisms to adjust the position of the nodes to



(a) – Initial placement. (b) – Final placement.

Figure 3: Example of execution of the local algorithm on torus with 900 nodes.

any distribution of route requests. Given a network infrastructure (e.g., a grid, data-center or on-chip-network) and a distribution on the source-destination requests, the expected path (route) length is an important measure for the performance, efficiency and power consumption of the network. We present a simple, local, and distributed algorithm that achieves good approximation to the optimal solution for the *minimum expected path length* problem for some specific topologies and requests distribution. In this work we also discuss requests that are *clustered* into disjoint groups. In such a setting our local algorithms are not guaranteed to always preform well anymore. Nevertheless, we present promising simulation results (see Figure 3) that consider random initial states of processes locations in the network. The paper [2] was submitted to INFOCOM 2012.

Additionally, it is important to mention my first published paper on the **virtual computer networks lab** that we build for the computer networks course. This virtual lab is capable to provide about 80 sets of equipment, while each set consists of 4 PCs , 4 routers, and 8 switches. The lab was built using Xen virtualization and occupies only two physical servers. This lab is successfully exploited already for three years. In 2009 we published a paper [9], and I presented it at the Computer Supported Education conference in Portugal.

List of papers under review

[1] C. Avin, M. Borokhovich, Y. Hadad, E. Kantor, Z. Lotker, M. Parter, and D. Peleg. Generalized perron-frobenius theorem for multiple choice matrices, and applications. *Submitted to ACM Symposium on Theory of Computing (STOC)*, 2012.

[2] C. Avin, M. Borokhovich, B. Haeupler, and Z. Lotker. Self-Adjusting Networks to Minimize Expected Path Length. *Submitted to IEEE Conference on Computer Communications (INFOCOM)*, 2012.

[3] C. Avin, M. Borokhovich, K. Censor-Hillel, and Z. Lotker. Order optimal information spreading using algebraic gossip. *Submitted to The International Journal Distributed Computing (DIST).*

[4] M. Borokhovich, C. Avin, and Z. Lotker. Tight bounds for algebraic gossip on graphs. *Submitted to Random structures and Algorithms Journal (RSA).*

[5] C. Avin, M. Borokhovich, A. Cohen, and Z. Lotker. Efficient Joint Network-Source Coding for Multiple Terminals with Side Information. *Submitted to IEEE Transactions on Communications.*

List of published papers

[6] C. Avin, M. Borokhovich, K. Censor-Hillel, and Z. Lotker. Order optimal information spreading using algebraic gossip. In *ACM Symposium on Principles of Distributed Computing (PODC)*, pages 363–372, 2011.

[7] C. Avin, M. Borokhovich, A. Cohen, and Z. Lotker. Efficient distributed source coding for multiple receivers via matrix sparsification. In *IEEE International Symposium on Information Theory (ISIT)*, pages 2045 –2049, 2011.

[8] M. Borokhovich, C. Avin, and Z. Lotker. Tight bounds for algebraic gossip on graphs. In *IEEE International Symposium on Information Theory (ISIT)*, pages 1758 –1762, 2010.

[9] C. Avin, M. Borokhovich, and A. Goldfeld. Mastering (virtual) networks - a case study of virtualizing internet lab. In *Proceedings of the First International Conference on Computer Supported Education (CSEDU)*, pages 250–257, 2009.

List of presentations in conferences

[1] C. Avin, M. Borokhovich, K. Censor-Hillel, and Z. Lotker. Order optimal information spreading using algebraic gossip. *ACM Symposium on Principles of Distributed Computing (PODC)*, San Jose, USA. June 2011.

[2] M. Borokhovich, C. Avin, and Z. Lotker. Tight bounds for algebraic gossip on graphs. *IEEE International Symposium on Information Theory (ISIT)*, Austin, USA, June 2010.

[3] M. Borokhovich, C. Avin, and Z. Lotker. Tight bounds for algebraic gossip on graphs. *10th Haifa Graph Workshop*, Haifa, Israel, May 2010.

[4] C. Avin, M. Borokhovich, and A. Goldfeld. Mastering (virtual) networks - a case study of virtualizing internet lab. In *Computer Supported Education (CSEDU)*, Lisboa, Portugal, March 2009.