The Quest for Universally-Optimal Distributed Algorithms

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Abstract

Many distributed optimization algorithms achieve an existentially-optimal round complexity (of $(\tilde{O}(\sqrt{n}+D))$, i.e., there exists some pathological worst-case topology on which no algorithm can be faster. However, most networks of interest allow for exponentially faster algorithms. This motivates two questions:

- What network topology parameters determine the complexity of distributed optimization?
- Are there universally-optimal algorithms that are as fast as possible on every single topology?

This talk provides an overview over the freshly-completed 6-year program that resolves these 25-year-old open problems for a wide class of global network optimization problems including MST, $(1+\epsilon)$-min cut, various approximate shortest path problems, sub-graph connectivity, etc. We provide several equivalent graph parameters that are tight universal lower bounds for the above problems, fully characterizing their inherent complexity. We also give the first universally-optimal algorithms approximately achieving this complexity on every topology.

The quest for universally-optimal distributed algorithms required novel techniques that also answer fundamental (open) questions in seemingly unrelated fields, such as, network information theory, approximation algorithms, (oblivious) packet routing, (algorithmic & topological) graph theory, and metric embeddings. Generally, the problems addressed in these fields explicitly or implicitly ask to jointly optimize ℓ_∞ & ℓ_1 parameters such as congestion & dilation, communication rate & delay, capacities & diameters of subnetworks, or the makespan of packet routings. In particular, results obtained on the way include the following firsts: (Congestion+Dilation)-Competitive Oblivious Routing, Network Coding Gaps for Completion-Times, Hop-Constrained Expanders & Expander Decompositions, Bi-Criteria (Online / Demand-Robust) Approximation Algorithms for many Diameter-Constrained Network Design Problems (e.g., (Group) Steiner Tree/Forest), Makespan-Competitive (Compact and Distributed) Routing Tables, and (Probabilistic) Tree Embeddings for Hop-Constrained Distances.

(Joint work with M. Ghaffari, G. Zuzic, D.E. Hershkowitz, D. Wajc, J. Li, H. Raecke, T. Izumi)

Brief Biography

Bernhard Haeupler's research interests lie in algorithm design, distributed computing, and (network) coding theory. Their research spans over 100 papers and won several awards including the ACM-EATCS Doctoral Dissertation Award of Distributed Computing, a George Sprowls Dissertation Award at MIT, and various best (student) paper awards. Bernhard's research has been funded by multiple prestigious awards including a Sloan Research Fellowship, an NSF Career Award, and an ERC award.

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