Tutorial T-12: Network Coding: From Theory to Practice

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Tutorial Overview

The tutorial provides an introduction to the rapidly growing research area of network coding focusing on use cases such as communication networks and storage. Network coding allows intermediate nodes in a network to manipulate data, for example by sending out packets that are combinations of previously received packets instead of simply forwarding them. For most practical purposes, these manipulations are linear operations over elements of a finite field. The initial theoretical results on network coding were followed by a wealth of applications in a number of different areas that show that the theoretical insights can be translated into practical gains. The tutorial is divided into three parts. The first part provides the participants with the theoretical tools necessary to understand the field of network coding and focuses on the underlying algebraic principles. We do not assume any prior knowledge of algebra or optimization. This part of the tutorial also introduces distributed randomized network codes and discusses their properties. The second part of the tutorial gives an overview of the different application areas and discusses the types of networking problems that are amenable to network coding (and those that aren't). In particular, it covers practical algorithms for data gathering in sensor networks, routing in wireless mesh networks, peer-to-peer networking and content distribution, streaming applications, etc. We illustrate how network coding can be used to increase throughput and robustness as well as reduce storage requirements, delay, and energy consumption. Finally, we discuss implementation aspects in real-world systems. Such systems may range from core network routers all the way down to mobile phones and tiny sensor nodes. The constraints imposed by these devices in terms of available memory and computing power may differ by several orders of magnitude. As a consequence, the encoding and decoding algorithms need to be carefully adapted to the specific problem at hand. As an example, the size of the finite field for the coding operations has an impact on network coding efficiency, but also on the encoding and decoding complexity. Coding operations may be sped up substantially through the use of specialized hardware, as evidenced by the successful implementation of network coding on Graphics Processing Units (GPUs). The energy consumed by the coding operations is of particular importance on mobile devices and needs to be considered to avoid offsetting the energy gains offered by network coding.

Presenter Biographies

Muriel Medard is the Cecil H. and Ida Green Professor of Electrical Engineering and Computer Science at MIT. She received B.S. degrees in EECS and in Mathematics in 1989, a B.S. degree in Humanities in 1990, a M.S. degree in EE 1991, and a Sc D. degree in EE in 1995, all from the Massachusetts Institute of Technology (MIT), Cambridge. She received several paper awards and was named by Thomson Reuters one the World's Most Influential Scientific Minds in 2014, based on citations. She was named a 2007 Gilbreth Lecturer by the National Academy of Engineering. She has served as President of the IEEE Information Theory Society and serves as Editor in Chief of the IEEE Journal on Special Areas in Communications.

Frank H. P. Fitzek Frank H. P. Fitzek is a Professor and chair of the communication networks group at Technische Universität Dresden coordinating the 5G Lab Germany. He received his diploma (Dipl.-Ing.) degree in electrical engineering from the University of Technology - Rheinisch-Westfälische Technische Hochschule (RWTH) - Aachen, Germany, in 1997 and his Ph.D. (Dr.-Ing.) in Electrical Engineering from the Technical University Berlin, Germany in 2002 and became Adjunct Professor at the University of Ferrara, Italy. In 2003 he joined Aalborg University as Associate Professor and later became Professor. He co-founded several start-up companies, e.g. acticom GmbH in Berlin in 1999. He has visited various research institutes including Massachusetts Institute of Technology (MIT), VTT, and Arizona State University. In 2005 he won the YRP award for the work on MIMO MDC and received the Young Elite Researcher Award of Denmark. He was selected to receive the NOKIA Champion Award several times in a row in 2007 to 2012. In 2008 he was awarded the Nokia Achievement Award for his work on cooperative networks. His current research interests are in the areas of wireless and mobile communication networks, mobile phone programming, cross layer as well as energy efficient protocol design and cooperative networking.