Tutorial T-17: 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 for communication networks, cloud storage and cloud computing. The tutorial will discuss its importance for the upcoming 5G communication system and how it can be integrated in Software Defined Networks (SDN), Network Function Virtualization (NFV), Content Centric Networks (CCN), WebRTC, wireless mesh networks, reliable Multicast, and many more. We will also explain how the new technology can be implemented using the software library KODO, which is already used by industry and research. The goal is to hold a lively tutorial with a lot of examples and demonstrations.

The first part of the tutorial provides the participants with the theoretical tools necessary to understand the field of network coding and focuses on the underlying algebraic principles. It will also introduce distributed randomized network codes and discuss their properties. We will not assume any prior knowledge of advanced algebra or optimization. Among other things, network coding can be used to increase throughput and robustness as well as reduce storage requirements, delay, and energy consumption. The second part of the tutorial gives an overview of the different application areas and discusses, which types of networking problems are amenable to network coding (and which 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. Finally, we will discuss implementation aspects in real-world systems using openstack and openflow. 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 speed 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.

1.) Introduction
2.) Algebraic foundations of network coding
    - Network code as operations at nodes
    - Min-cut/max-flow from an algebraic perspective
    - Random linear codes
    - Generalizations to correlated sources
    - Beyond multicast
3.) Optimization aspects

- Moving away from trees – convex optimization of network coding
    - i. Distributed optimization
    - ii. Applications to P2P download time optimization
- Optimality of dissemination time –algebraic gossip
- File dissemination time in wireless systems

4.) Implementation of RLNC oriented approaches

- Impact of generation and field size
- Systematic codes
- Designing rules for network coding
- Software library

5.) Software Defined Network (SDN)

6.) Distributed Storage

7.) TCP and network coding

- Combining coding with sliding windows
- Network combining

8.) Examples of network coding on in the real works (LIVE DEMONSTRATION) • Reliable Multicast

- Distributed Storage
- Performance on Mobile Phones

Presenter Biographies

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 the same year. In 2003 he joined Aalborg University as Associate Professor and later became Professor. He co-founded several start-up companies starting with 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 from 2007 to 2011. In 2008 he was awarded the Nokia Achievement Award for his work on cooperative networks. In 2011 he received the SAPERE AUDE research grant from the Danish government and in 2012 he received the Vodafone Innovation price. In 2015 he was awarded the honorary degree "Doctor Honoris Causa" from Budapest University of Technology and Economy (BUTE).

Muriel Médard is a Professor in the Electrical Engineering and Computer Science at MIT. Professor Médard 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 serves as an associate editor for the IEEE/OSA Journal of Lightwave Technology and is a member of the Board of Governors of the IEEE Information Theory Society. Professor Médard's research interests are in the areas of network coding and reliable communications, particularly for optical and wireless networks. She was awarded the IEEE Leon K. Kirchmayer Prize Paper Award 2002 for her paper, "The Effect Upon Channel Capacity in Wireless Communications of Perfect and Imperfect Knowledge of the Channel. She was co- awarded the Best Paper Award for G. Weichenberg, V. Chan, M. Médard, "Reliable Architectures for Networks Under Stress". She received a NSF Career Award in 2001 and was co-winner 2004 Harold E. Edgerton Faculty Achievement Award, established in 1982 to honor junior faculty members "for distinction in research, teaching and service to the MIT community." She was named a 2007 Gilbreth Lecturer by the National Academy of Engineering. Professor Médard is a House Master at Next House and a Fellow of IEEE.