"Wireless caching towards 5G: network coding and PHY considerations"

Tutorial for ICC-2016

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Abstract:

The challenge to sustain the giant leap in volume and societal impact of wireless communications, has spurred worldwide research to produce radically new spectrum & power efficient, high-performance, and environmentally-friendly communication technologies. In this effort, caching has recently joined feedback-aided multiuser MIMO as one of the most powerful tools towards the ultimate promise of having wireless networks with throughputs that scale with the number of network users.

This tutorial will provide a new look at the recent efforts to employ caching as something "on top" of physical layer communications, while on the other hand we will also review the very recent research that directly combines and fuses the two elements of caching and PHY. Towards this we will offer an educational overview of the latest progress in designing algorithms that manage to handle multiuser interference by using cache-aided and feedback-aided MIMO techniques, to (often jointly) elevate performance, from that of serving one user at a time (TD), to the much higher performance where many users are served simultaneously and seamlessly without interference. While exploring the interesting interplay between caching and feedback-aided multiuser MIMO communications, we will also see how content prediction – of a predetermined library of files during the night (off peak hours) – and a subsequent caching of parts of this library content again during the night, may go beyond boosting performance, and may in fact offer the additional benefit of alleviating the need for prediction, estimation, and communication of CSIT during the day.

Outline of the Tutorial

- Basic exposition of the challenges of modern wireless communications
  - Opportunities and bottlenecks in different feedback-aided PHY technologies like Massive MIMO, and multi-cell cooperation and densification
  - The need of a new technology
- Brief introduction to cache-aided solutions
  - Moore's Law for bandwidth
- Basic elements of coded caching
  - Local vs. global caching gains
- Centralized vs. decentralized coded caching in multicast settings
- Exploiting file popularity
  - Multiple groupcast index coding, and other techniques
- Performance outer bounds – basic exposition
- Source-coding view of coded caching
- Joint considerations of caching and network topology
- Exploiting small cache sizes
  - Joint caching-and-delivery algorithms designed for ultra-small cache sizes
- Exponential subpacketization of coded caching

- Fundamental differences between wired and wireless coded caching – non separability
- Caching in feedback-aided multiuser MIMO settings
  - Joint caching and precoding schemes
- Centralized multi-server problem: ripping the gains of both words
- Caching at both transmitters and receivers (Cache-aided interference channel)
- Benefits of caching in large MIMO systems

    - Cache-aided performance improvements
    - Cache-aided simplifications in implementation
- The fundamental interplay between coded-caching and feedback
- Competing + synergistic duality between feedback and caching
- Caching to achieve interference management
    - Caching at the transmitters to achieve interference alignment
    - Caching to give receivers, interference-reducing side information
- Caching to alleviate the backhaul in interference-limited settings
- Coded-caching as a means of creating joint-transmission opportunities
- Exploring the interplay between coded caching and feedback
    - Achieving an exponential utility of caching in massive MIMO settings
    - Combining multicast gains from caching, with broadcast gains from feedback-aided multiuser MIMO
    - Interesting (competing + synergistic) duality between feedback and memory (caching)
- Coded caching in a variety of wireless networks
    - Wireless multihop D2D caching networks
    - Cache-aided Wyner networks
    - Coded caching in erasure networks
    - Femtocaching
    - Caching on the edge
- Theoretical and practical open problems

Speaker Biography

Petros Elia received the B.Sc. degree from the Illinois Institute of Technology, and the M.Sc. and Ph.D. degrees in electrical engineering from the University of Southern California (USC), Los Angeles, in 2001 and 2006 respectively. Since February 2008 he has been an Associate Professor with the Department of Mobile Communications at EURECOM in Sophia Antipolis, France.

His latest research deals with the intersection of coded caching and feedback-aided communications in multiuser settings. He has also considered different problems in the area of complexity-constrained communications, MIMO, cooperative and multiple access protocols and transceivers, complexity of communication, as well as with isolation and connectivity in dense networks, queueing theory and cross-layer design, coding theory, information theoretic limits in cooperative communications, and surveillance networks. He is a Fulbright scholar, the co-recipient of the SPAWC-2011 best student paper award on the topic of reduced complexity bidirectional communication with limited feedback, and of the NEWCOM++ distinguished achievement award 2008-2011 for a sequence of publications on the topic of reduced complexity multimode communications in the presence of little or no feedback. On these two topics he has also presented many tutorial in different flagship conferences. In terms of the tutorial, the speaker provided a complete characterization of the effect of feedback timeliness and quality on network performance for specific networks, and his recent work deals with directly combining the elements of caching and PHY in wireless networks, exploiting the fundamental differences between wired and wireless coded caching, exploring the use of caching in feedback-aided multiuser MIMO settings, in understanding the benefits of caching in large MIMO systems, and on the fundamental interplay between coded-caching and feedback.