Tutorial : Fronthaul Compression for Cloud Radio Access Networks

Presenters : Abdellatif Zaidi (Université Paris-Est and France Research Center, Huawei France) and Inaki Estella Aguerri (France Research Center, Huawei France).

Tutorial Overview :

Cloud radio access networks (CRAN) provide a new architecture for next-generation wireless cellular systems in which the baseband processing is moved from the base stations (BSs) to a central processor (CP) in the "cloud". The BSs operate as simple radio units (RUs) and are connected to the CP via fronthaul links. The fronthaul links carry information about the baseband signals, in the form of quantized inphase and quadrature (IQ) samples. This CRAN architecture is generally seen as a possible means of enabling interference management at the geographical scale covered by the distributed radio units, through the allowed joint processing at the CP. Also, it has some other appreciable features, such as low cost deployment of BSs and flexible network utilization.

Due to the large volumes of the quantized IQ signals, compression prior to transmission on the fronthaul links is critical. Current solutions, which are the object of various standardization efforts, prescribe the use of conventional scalar quantizers for this purpose. However, with this approach, fronthaul links are known to impose an important bottleneck to the system performance. Therefore, more advanced forms of compression are needed and are receiving considerable interest.

Multiterminal compression allows for the joint processing of the compressed IQ samples of different RUs at the CP. Specifically, in the uplink, joint decompression enables the CP to leverage the correlation among the signals received by neighboring RUs through Wyner-Ziv coding. In the downlink, the joint compression allows the CP to correlate the quantization noises of the baseband signals transmitted by neighboring RUs, through multivariate compression.

Multiterminal compression uses unstructured quantization codebooks that are designed independently of the channel codebooks used for transmission on the wireless channel. A conceptually different technique, which employs structured codebooks, leads to new strategies for the CRAN that are based on the framework of compute-and-forward.

This tutorial is aimed at providing a survey of the work in the area of fronthaul compression with emphasis on advanced signal processing solutions, based on communication and information theoretic concepts. Specifically, the main ideas that are brought to bear from network information theory are *multiterminal compression* and *structured coding*.

Level / Pre-requisites

The tutorial is open to a wide audience working on signal processing, communication,

networking and information theory, from both academia and industry. Basic ingredients will be reviewed and ; so, no particular pre-requisites are required.

Tutorial Outline :

The tutorial is structured into two parts. The total duration is **three hours**, including half an hour break.

I. Introduction : Cloud radio access networks

II. Point-to-point solutions, standard quantization / compression

II. Uplink scenarios
   A. Distributed fronthaul compression, Wyner-Ziv compression
   B. Structured coding, compute-and-forward
   C. Denoising / in-network compression

III. Downlink scenarios
   A. Multivariate fronthaul compression
   B. Structured coding, reverse compute-and-forward
   C. Enumeration

IV. Examples

V. Concluding remarks

Presenters' biographies

Abdellatif Zaidi, received the B.S. degree in Electrical Engineering from ENSTA ParisTech, Paris, in 2002 and the M. Sc. and Ph.D. degrees in Electrical Engineering from TELECOM ParisTech, Paris, France in 2002 and 2006, respectively.

From December 2002 to March 2006, he was with the Communications an Electronics Dept., TELECOM ParisTech, Paris, France and the Signals and Systems Lab., CNRS/Supélec, France pursuing his PhD degree. From May 2006 to September 2010, he was at École Polytechnique de Louvain, Université Catholique de Louvain, Belgium, working as a research assistant. Dr. Zaidi was "Research Visitor" at the University of Notre Dame, Indiana, USA, during fall 2007 and Spring 2008, and the Technical University of Munich during Summer 2014, and the Ecole Polytechnique Federale de Lausanne, EFPL, Switzerland. He is an associate professor at Université Paris-Est, France ; and on leave since Jan. 2015 at the Mathematics and Algorithmic Sciences Lab., France Research Center, Huawei France.

His research interests cover a broad range of topics from network information theory, coding and communication theory, as well as multiterminal source coding, with application to diverse problems of data transmission and compression in networks. A. Zaidi serves as Associate Editor of the Eurasip Journal on Wireless Communications and Networking (EURASIP JWCN). Dr. Zaidi is the co-recipient (jointly with Shlomo Shamai (Shitz)) of the N# Best Paper Award, as well as the French Excellence in Research price. He has publi-

shed more than 80 international journal and conference papers, and gave several keynote speeches and tutorials.
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Iñaki Estella Aguerri, received his B.Sc. and M.Sc. degrees in Telecommunication Engineering from Universitat Politècnica de Catalunya (UPC), Barcelona, Spain, in 2008 and 2011, respectively, and the Ph.D. degree in Electrical Engineering from Imperial College London, London, UK, in 2014. From 2008 to 2013, he was Research Assistant at Centre Tecnològic de Telecomunicacions de Catalunya (CTTC) in Barcelona, Spain. He was Visiting Scholar at Stanford University in summer 2012, and he pursued his B.Eng thesis at the Eindhoven University of Technology in the Biomedical Image Analysis group in 2008. In November 2014, he joined the Mathematical and Algorithmic Sciences Lab, France Research Center, Huawei Technologies Co. Ltd., Boulogne-Billancourt, France. His current research interests lie in the areas of information theory and communication theory, with emphasis on multi-terminal source and channel coding, and its applications in for data communications and compression in wireless networks.