Tutorial T-14: Centralized Radio Access Networks: Moving Basedband to the Cloud

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Tutorial Overview

The focus of this tutorial is centralized radio access networks (C-RANs), a revolutionary new architecture that moves the signal processing required for a mobile device to communicate with the network away from the point of reception and into the cloud. C-RAN is motivated by the current trend towards densification and the corresponding explosion in the number of deployed cellular base stations. While economies of scale will drive down equipment prices to some degree, future networks will make increasing use of advanced signal processing algorithms with costly computational requirements. By connecting remote radio heads to baseband processing assets through a fronthaul, much of the computational burden can be shifted to a central processing center. C-RANs can leverage advances in cloud computing, virtualization, and open IT platforms, making baseband processing a commodity. For C-RAN systems, the additional costs and delays imposed by the fronthaul is a concern, so the benefits of centralized processing must offset these factors while maintaining a high quality of experience for the user. The tutorial covers new concepts that are required for the design, operation, and optimization of centrally processed radio access networks, fronthaul networks, operations and management algorithms, and architectural elements.

The tutorial focuses on C-RAN's impact on how future mobile networks will be viewed. Most notably, the tutorial emphasizes the distinctions between the logical and the physical architecture; i.e., traditionally, Standards Developing Organizations (SDOs) such as 3GPP consider only logical aspects such as logical entities, which perform a pre-defined set of functions and logical interfaces which allow for communicating among these logical entities. The ability to fully or partly centralize mobile network functionality implies the need for small and medium sized data centers that perform the mobile network functionality. The placement of these data centers and the structure of the physical implementation may vary strongly depending on the existing fronthaul and backhaul. Furthermore, the deployed hardware at these data centers may be commodity computation and storage hardware, or it may be a mix of commodity and specialized hardware. All these different aspects need to be considered by the mobile network architecture in order to provide high flexibility and adaptability to different physical implementations of the same logical mobile network.

Detailed Organization

Part 1: Motivation Behind C-RAN

- Overview: The tutorial begins with an overview of the C-RAN system architecture,
- Motivating Example: Basic C-RAN concepts are illustrated by a example involving the central processing of the LTE uplink.
- Densification and Interference: The trend towards densification is reviewed, with an emphasis on the role of interference.

Part 2: Case Studies

- Integration: Overview of current mobile network architectures and how Cloud-RAN would integrate into these architectures.
- Virtualization: The concepts of software defined networking (SDN) and network function virtualization (NFV) are covered, with an emphasis on their applicability to a mobile network including the radio access network.
- Case Studies: In order to show the peculiarities of Cloud-RAN, we use specific use cases, show practical deployments and their implications on the operation of a Cloud-RAN, and we provide a quantitative overview on the requirements and benefits of Cloud-RAN.

Part 3: Implementation Issues

- Analysis of Complexity Issues: an analysis of the computational requirements associated with central processing is provided, which gives some insight into how to properly size and locate the computing center.
- Fronthaul Compression: The role of the fronthaul is considered, with an emphasis on compression techniques.
- Functional Split: New functional splits between remote radio heads and baseband processing assets are visited and new directions towards optimization of fronthaul transport are presented.
- Scheduling: New approaches for scheduling in a C-RAN are proposed, which take into account the constraints of the fronthaul and the centralized processing assets.
- Novel Uses: Novel uses of C-RAN architectures are covered, including techniques to selectively shut down radio heads during off-peak hours and the use of collaborative/distributed processing techniques, such as network-MIMO, and enhanced inter-cell interference coordination (eICIC).
- Economics: An economic analysis is provided, balancing the costs of the fronthaul, base stations, and computing centers. A review of relevant SDO activities is presented.

Presenter Biographies

Matthew Valenti is a Professor in the Lane Department of Computer Science and Electrical Engineering at West Virginia University. His research is in the area of wireless communications, including wireless cellular networks, military communication systems, sensor networks, mobile cloud computing, and transmission technology. Dr. Valenti received his BSEE and Ph.D. from Virginia Tech, his MSEE from Johns Hopkins, and worked as an Electronics Engineer at the US Naval Research Laboratory. He is active in the organization of major conferences, including serving as the (Unclassified) Technical Program Chair for MILCOM 2016, Technical Program Vice Chair for MILCOM 2015 and Globecom 2013, and as a track or symposium chair for MILCOM ('10,'12,'14), ICC ('09,'11), Globecom (’15), and VTC ('07). He is on the technical steering committees for MILCOM (the MILCOM Board) and Globecom/ICC (GITC). He is Editor in Chief for *IEEE ComSoc’s Best Readings*, an Executive Editor for *IEEE Transactions on Wireless Communications*, and the Chair of *ComSoc's Communication Theory Technical Committee (CTTC)*.

Peter Rost received his Ph.D. degree from Technische Universität Dresden, Dresden, Germany, in 2009 under supervision of Prof. G. Fettweis, and his M.Sc. degree from University of Stuttgart, Stuttgart, Germany, in 2005. Peter has been with Fraunhofer Institute for Beam and Material Technologies, Dresden, Germany; IBM Deutschland Entwicklung GmbH, Böblingen, Germany; and NEC Laboratories Europe, Heidelberg, Germany. Since May 2015, Peter is member of the Radio Systems research group at Nokia Networks, Munich, Germany, where he contributes to the European H2020 projects 5G-NORMA and METIS-II, and works in business unit projects on 5G Architecture. Peter has been involved in several EU projects (e.g. FP7 iJOIN as Technical Manager), and standardization (e.g. 3GPP RAN2). Currently, Peter serves as member of IEEE ComSoc GITC, IEEE Online GreenComm Steering Committee, and VDE ITG Expert Committee Information and System Theory. He is an Executive Editor of IEEE Transactions of Wireless Communications. Peter further supported several conferences; e.g. IEEE ICC 2009 (Local Organization) and IEEE VTC Spring 2013 (TPC Chair). Peter published more than 40 scientific publications and he is author of multiple patents and patent applications.

Aleksandra Checko received her double M.Sc. degree in telecommunication from the Technical University of Denmark (DTU) and Lodz University of Technology, Poland (PŁ) in 2011. She has been working as a telecommunication trainer conducting courses on GSM, UMTS, LTE and VoLTE solutions internationally. She is now pursuing an industrial Ph.D. at DTU Fotonik (in the Networks Technology and Service Platforms Group) and MTI Radiocomp, focusing on C-RAN architecture and fronthaul design. She participated in 5G fronthaul research group at Foxconn, FP7 European project HARP as well as in the Danish national project SAIRS.

She gave a number of seminars and lectures on C-RAN and C-RAN fronthaul this year (2015) including one in Bell Labs, Alcatel-Lucent France and at the iJOIN winter school in Bremen. She served as a reviewer for several journals and conferences, including: IEEE Transactions on Vehicular Technology, IEEE Journal on Selected Areas in Communications, IEEE ICC 2015, IEEE WCNC 2016, VTC 2016-Spring, WTS 2015, EW 2014 and IEEE GreenComm 2013. Her interests include mobile networks, especially their architecture, protocols and capacity planning methods. Several of Ms. Checko’s

papers are on C-RAN, including a tutorial paper that has appeared in *IEEE Communication Surveys and Tutorials*.