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Fifth International Workshop on

Cloud Technologies and Energy Efficiency in Mobile Communication Networks

CLEEN 2017

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How cloudy and green will mobile network and services be?

22 June 2017, Turin, Italy

Workshop programme:

09:00	Registration
09:15	Welcome and presentation by the workshop chair (Dario Sabella, Intel)
09:20	Key Note #1: AEIT activities on innovative systems (Maurizio Mayer)
09:30	Keynote #2: Enabling Communication Services for Vertical Industries through Network Slicing and Mobile Edge Cloud (Peter Rost, Nokia Bell Labs)
10:00	Technical session #1 - Advanced Network Technologies • N. Molner et al., "The 5G-Crosshaul Packet Forwarding Element pipeline: measurements and analysis" • G. Nardini et al., "Scalability and energy efficiency of Coordinated Scheduling in cellular networks towards 5G" • N. Iardella et al., "A testbed for flexible and energy-efficient resource management with virtualized LTE-A nodes"
11:00	Networking coffee break @ 5G PoC Zone + Posters (*)
11:20	Technical session #2 - Advanced Radio Technologies • P. Rosson et al., "SDR based test bench to evaluate analog cancellation techniques for In-Band Full-Duplex Transceiver" • S. Andersson et al., "Design Considerations for 5G mm-Wave Receivers"
12:00	Keynote #3:Merging millimeter-wave and mobile edge computing technologies in 5G networks: Opportunities and challenges (Sergio Barbarossa, Univ. La Sapienza, Rome)
12:30	Networking lunch break @ 5G PoC Zone + Posters (*)
14:00	Technical session #3 - Advanced Networks Energy Efficiency • Y. Yang, D. Sabella, "Mobile Network Energy Efficiency Optimization in MIMO Multi-Cell Systems" • N. Bartzoudis et al., "Energy footprint reduction in 5G reconfigurable hotspots via function partitioning and bandwidth adaptation"
14:40	Panel discussion (moderator: Emilio Calvanese-Strinati, CEA)
15:40	Wrap-up & closing by the Workshop Chair
16:00	End of workshop

(*) Poster presentations:

- Thomas Deiß et al., "Dataplane measurements on a Fronthaul and Backhaul integrated network"
- Claudia Carciofi et al., "Effect of network architecture on power consumption in mobile radio systems"
- Martti Forsell, Tapio Rautio, "Flexible and Programmable Solution for 5G Baseband Processing"
- Giuseppe Avino et al., "Energy-Efficient 5G Networks: Optimization Meets SDN"

Detailed CLEEN2017 workshop programme

9.15-9.20 Welcome and presentation by the workshop chair (Dario Sabella, Intel)

9.20-9.30 **Keynote #1**: Maurizio Mayer: "AEIT activities on innovative systems"

9.30-10.00 **Keynote #2**: Enabling Communication Services for Vertical Industries through Network Slicing and Mobile Edge Cloud (Peter Rost, Nokia Bell Labs)

10.00-11.00 **Technical Session #1 – Advanced network technologies**

Paper # 1570357053

N. Molner et al., "The 5G-Crosshaul Packet Forwarding Element pipeline: measurements and analysis"

Abstract—This paper is focused on the 5G-Crosshaul Packet Forwarding Element (XPFE), which is the packet forwarding element of the 5G-Crosshaul network architecture. The XPFE integrates multiple technologies which allow to transport traffic from multiple tenants and of different nature over the same infrastructure. Hence, the paper is focused on the performance of this essential element of our network, providing some end-to-end delay measurements and analyzing the behavior of this delay. Likewise, we have fitted the appropriate probability distribution for these measurements, which allows us to infer some confidence intervals for the prediction of the maximum number of hops supported by delay-sensitive fronthaul traffic before being processed in a 5G-Crosshaul Processing Unit.

Keywords —5G, 5G-Crosshaul, fronthaul, backhaul, Multitenancy, SDN, NFV, delay, latency.

Paper # 1570354178

G. Nardini et al., "Scalability and energy efficiency of Coordinated Scheduling in cellular networks towards 5G"

Abstract—Coordinated Scheduling (CS) is one of the main techniques to control inter-cell interference in present (4G) and future (5G) cellular networks. We show that coordination of a cluster of nodes can be formulated as an optimization problem, i.e., placing the Resource Blocks in each node's subframe with the least possible overlapping with neighboring nodes. We provide a clever formulation, which allow optimal solutions to be computed in clusters of ten nodes, and algorithms that compute good suboptimal solutions for clusters of several tens of nodes, fast enough for a network to respond to traffic changes in real time. This allows us to assess the relationship between the scale at which CS is performed and its benefits in terms of network energy efficiency and cell-edge user rate. Our results show that optimal CS allows a significant protection of cell-edge users. Moreover, this goes hand-in-hand with a significant reduction in the number of allocated Resource Blocks, which in turn allows an operator to reduce its energy consumption. Both benefits actually increase with the size of the clusters.

Keywords—CoMP-CS, energy-efficiency, scheduling, mobile networks, optimization, simulation

Paper # 1570357032

N. Iardella et al., "A testbed for flexible and energy-efficient resource management with virtualized LTE-A nodes"

Abstract—This paper describes the software architecture and the implementation of a fully operational testbed that demonstrates the benefits of flexible, dynamic resource allocation with virtualized LTE-A nodes. The testbed embodies and specializes the general software architecture devised within the Flex5Gware EU project, and focuses on two intelligent programs: the first one is a Global Scheduler, that coordinates radio resource allocation among interfering nodes; the second one is a Global Power Manager, which switches on/off nodes based on their expected and measured load over a period of minutes. The software framework is written using open-source software, and includes fast, scalable optimization algorithms at both components. Moreover, it supports virtualized BaseBand Units, implemented using OpenAir-Interface, that can run on physical and virtual machines. We present the results obtained via on-field measurements, that demonstrate the feasibility and benefits of our approach.

Keywords—Coordinated Scheduling, power saving, software framework, Cloud-RAN, testbed, OpenAirInterface, Flex5Gware

11.00-11.20 **Networking coffee break** @ 5G PoC Zone + Posters presentations

11.20-12.00 **Technical Session #2 – Advanced Radio technologies**

Paper # 1570357314

P. Rosson et al., “SDR based test bench to evaluate analog cancellation techniques for In-Band Full-Duplex Transceiver”

Abstract—In-Band Full-Duplex transmissions are promising solutions for wireless 5G small cell communication scenarios. It allows to increase the overall capacity under certain conditions. In this paper we evaluate two combined techniques to mitigate the analog self-interference. Instead of using high performance components with high linearity and high bandwidth for a frequency band, a single SDR chip has been chosen. Based on its characteristics and its simple architecture, a compact and low complexity test bench is proposed to reduce the undesired self-interference. The analog self-interference cancellation reaches 71 dB over 40 MHz bandwidth with a transmitted power of 12 dBm.

Keywords—In-Band Full-Duplex (IBFD); Analog Self-Interference Cancellation (SIC); Software Defined Radio (SDR)

Paper # 1570357426

S. Andersson et al., “Design Considerations for 5G mm-Wave Receivers”

Abstract—To meet yet higher speed and capacity demands, 5G will turn to mm-waves for more bandwidth. In this paper some receiver design issues occurring when moving from current 4G bands to mm-wave frequencies are discussed. The local oscillator phase noise increases by 6 dB/octave with frequency and will ultimately limit spectrum efficiency. To analyze this, a phase noise model, based on a test chip designed in 28nm FDSOI, is presented. Provided is also a thorough analysis on the wideband receiver noise figure evolution that shows an expected noise figure increase from 5.1 dB to 9.1 dB when shifting from 2 GHz to 30GHz carriers. By taking advantage of the anticipated improvements from CMOS scaling, it is shown that 10 years from now, the receiver noise figure will improve to 7.7 dB at 30 GHz. The presented mm-wave integration aspects also account for beamforming and array antennas, and how this relates to building practice, power consumption and area.

12.00-12.30 **Keynote #3**: Merging millimeter-wave and mobile edge computing technologies in 5G networks: Opportunities and challenges (Sergio Barbarossa, Univ. La Sapienza, Rome)

12.30-14.00 **Networking lunch break** @ 5G PoC Zone + Posters presentations

14.00-14.40 **Technical Session #3 – Advanced Networks energy efficiency**

Paper # 1570357334

Y. Yang and D. Sabella, Mobile Network Energy Efficiency Optimization in MIMO Multi-Cell Systems

Abstract—In this paper, we consider the energy efficiency maximization problem in downlink multi-input multi-output (MIMO) multi-cell systems, where all users suffer from intercell interference. To solve this optimization problem with a nonconcave objective function and a complex-valued matrix variable, we extend the recently developed successive pseudoconvex approximation framework and propose a novel iterative algorithm that has the following advantages: 1) fast convergence as the structure of the original optimization problem is preserved as much as possible in the approximate problem solved in each iteration, 2) easy implementation as each approximate problem is natural for parallel computation and its solution has a closed-form expression, and 3) guaranteed convergence to a stationary point. The advantages of the proposed algorithm are also illustrated numerically in terms of energy efficiency gains from mobile network infrastructure perspective.

Keywords —Energy Efficiency, Interference-limited System, MIMO, Nonconvex Optimization, Pseudoconvex optimization

Paper # 1570357380

N. Bartzoudis et al., “Energy footprint reduction in 5G reconfigurable hotspots via function partitioning and bandwidth adaptation”

Abstract—Cloud-based radio access networks (C-RAN) are expected to face important challenges in the forthcoming fifth generation (5G) communication systems. For this reason, more flexible C-RAN architectures have recently been proposed in the literature, where the radio communication stack is partitioned and placed across different RAN nodes to tackle the 5G capacity and latency requirements. In this paper, we show that this functional split also supports energy efficiency, especially when it is combined with bandwidth adaptation. To this aim, we have built a dynamic hotspot prototype, where the hardware-accelerated physical-layer is placed in the remote radio head, and higher software-based layers are placed in a server (either directly connected or remotely accessible). This setup allowed us to experimentally evaluate the power consumption of key hardware modules when adapting the bandwidth and the modulation and coding scheme. The real-time operation of the testbed allows further experimentation with different 5G use cases and the evaluation of other key performance indicators.

Keywords: HW-SW partitioning, 5G networking, 5G dynamic hotspots, energy efficiency, reconfigurability, power measurements.

14.40-15.40 **Panel discussion (moderator: Emilio Calvanese-Strinati, CEA)**

15.40-16.00 **Wrap-up & closing by the Workshop Chair**