



Converged Optical-Mobile Access Networks with Dynamic and Efficient Resource allocation

Editorial

This is the third newsletter of COMANDER, aiming to highlight the most important action points that took place during the last two years of the project regarding dissemination and, outreach activities, technical achievements and new secondments.

The Project

COMANDER brought together and inter-exchange experts from Industry and academia with the long-term goal of delivering a state of the art, cutting-edge and cost-efficient approach to the problem of Next-Generation Fiber-Wireless Access Networks (NGN). The design of NGN has since long dictated the necessity to merge the currently distinct optical and wireless infrastructures into a unified network capable of offering the best of both worlds: the stability and ultra-high speeds of optical fiber networks with the agility and flexibility of wireless networks. In an attempt to revolutionize the networks of the future, COMANDER investigated the convergence of the optical networks with ultra-high speed 60GHz wireless signals that will boost wireless connectivity to new levels capable of handling the ever-increasing data demand.

COMANDER facts

Contract number

FP7-People-2013-IAPP-612257

Project coordinator

Aristotle University of Thessaloniki -
AUTH

Contact person

Prof. Nikos Pleros

Project consortium

Academia

- Aristotle University of Thessaloniki –AUTH- Greece
- Technical University of Berlin – TUB - Germany

Industry

- Iquadrat – IQU -Spain
- Phoenix Software B.V. – PHX –The Netherlands

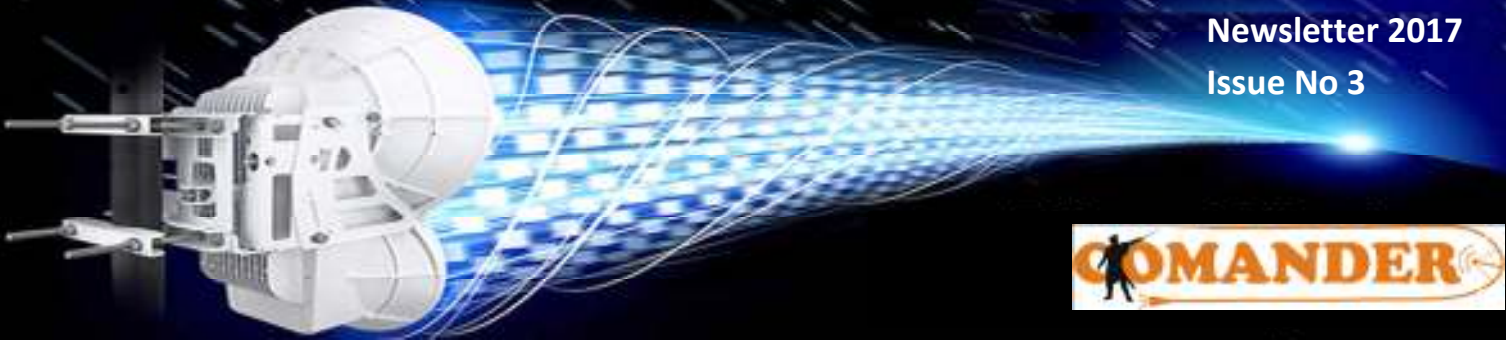
Project website

<http://www.mc-comander.eu>

Community contribution to the project: 1.448.294 Euro

Launched on: 1st October 2013

Duration: 4 years



Technical Progress & Highlights during 3rd and 4th year

During the last 24 months of the COMANDER project, work has been performed as planned in the following tasks:

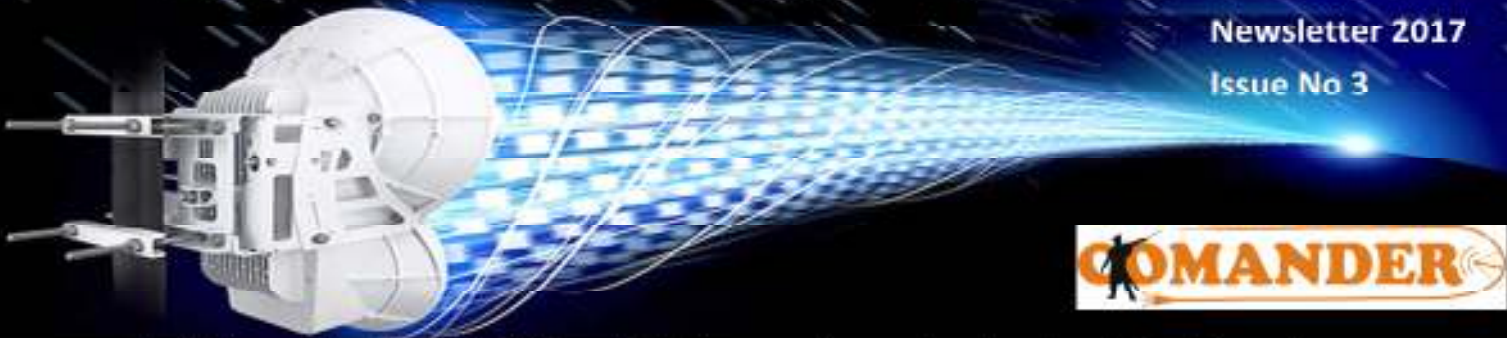
- **COMANDER NETWORK DESIGN AND SPECIFICATIONS:** The architecture and spectral arrangement for the converged FTTH plus-60GHz RoF network has been completed, i.e. an alternative COMANDER network architecture, compatible with Cloud-RAN paradigm was also designed. In this scenario multi-tier COs have been introduced to decrease power budget and extend access network reach.
- **OPTICAL ACCESS POINT MODULE (APM) - DESIGN AND FABRICATION:** The COMANDER consortium embarked on a Multi Project Wafer (MPW) platform of the EU-funded JePPIX PARADIGM project (Photonic Advanced Research and Development for Integrated Generic Manufacturing) to design and integrate the Access Point Module on a Photonic Integrated Chip (PIC). The APM PIC included several tunable radio frequency transmitters and optical receivers on a Indium Phosphide platform, benefitting from the generic integration technology and use of standardized building blocks, available through dedicated software tools and Process Design Kits (PDKs). The application was approved and the proposed APM chip has been fabricated using III-V photonic platforms by both Oclaro and HHI fabs. The HHI chip was delivered on June 2015 and the Radio Access Unit (RAU) was semi-packaged by Technische Universiteit Eindhoven (TUE), one of the PARADIGM partners.



Fig. 1. PIC evaluation platform: application specific (AS) PIC; aluminum block (AL block); Ground-Signal-Ground (GSG) RF probe, fiber array unit (FAU).

One more achievement of the project is the efficient design transfer methods for complex PICs that were developed by the COMANDER consortium. With the use of generic photonic building blocks in the applied design environment, the migration between different foundries is facilitated, and therefore the efficiency of our design cycle is increased.

- **MODULATION FORMATS AND TRANCEIVERS:** The CO optical circuit was designed and tested via simulations for different modulation formats (ASK and BPSK) in sub-carrier multiplexed, complete TxRx arrangements. WDM functionality was also tested by using four optical channels simultaneously.
- **CO-APM TRANSMISSION AND NETWORK CODING SIMULATIONS:** The Central Office (CO) and Access point module (APM) optical circuits have been designed and simulated as end-to-end transmission links. Towards enhanced network throughput and network resiliency, the first



physical layer all-optical digital Network Coding scenario was developed and tested for various modulation formats (OOK, BPSK and DQPSK) in 60 GHz sub-carrier modulated signals.

- 60 GHz ANTENNA: The 60 GHz antenna system along with the optical receiver and transmitter of the APM has been simulated and designed for: 1) Rectangular patch microstrip antenna 2) Square patch microstrip antenna 3) Hexagonal microstrip patch antenna and 4) Circular patch microstrip antenna.
- MAC-BASED NETWORK CONTROL PROTOCOLS: The basic principles, concepts and operational rules of the network intelligent administration were implemented using a Medium-Transparent Access Control protocol. The MT-MAC based protocol was evaluated through simulation and analytical tools. A fairness enhancement algorithm was also developed that enables the MT-MAC protocols to evenly distribute the network's resources. A preliminary analytical framework was developed for calculating the delay in an optical-wireless network with QoS support.

Outreach and Dissemination Activities

- The consortium has produced and distributed a brochure that targets a broad audience spectrum and explains in simple terms the project's goals and potential outcomes.
<http://www.mc-comander.eu>



- Two workshops have been organized by the COMANDER consortium on "Fiber-Wireless Network Technologies and Architectures towards 5G and Beyond" and took place in Trento, Italy and Girona, Spain during the 18th and 19th International Conference on Transparent Optical Networks (ICTON) in 2016 and 2017 respectively (<https://icton2016.fbk.eu/> and <http://www.itl.waw.pl/icton2017>).
- A Special Session on Smart Grids in the IEICE Information and Communication Technology Forum (ICTF) 2016 conference that took place between 6-8 of July 2016 In Patras, Greece.
- A special session on Communications and information processing for the smart grid during the International Workshop on Computer-Aided Modeling Analysis and Design of Communication Links and Networks (CAMAD) 2017 with focus on analytical and simulation tools and techniques for the performance evaluation of communications systems.



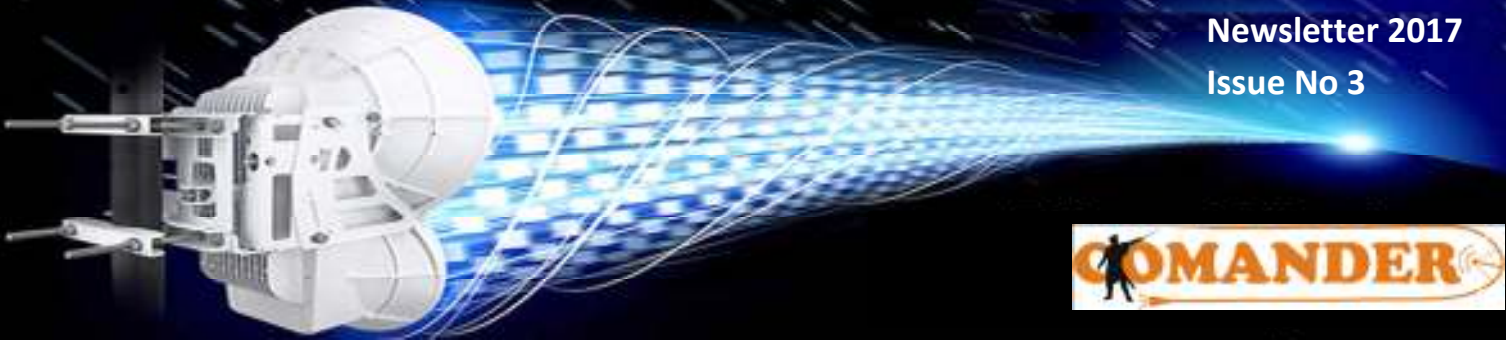


- One OPEN DAY was organized by Aristotle University of Thessaloniki (AUTH) on 9th March 2017 at AUTH premises, where an overview of the research at the Wireless and Photonics Systems Research Group was presented to undergraduate, graduate and post-graduate students from the department of Informatics, AUTH. Moreover, professor Nicholas Madamopoulos, from the Department of Aeronautical Sciences Hellenic Air Force Academy Dekeleia, Greece was invited to present his work on “Multifunctional Photonic Signal Processing Platforms for Analog and Digital Communication Systems”, which forms a common linearization platform for electric field coming from any Mach-Zehnder-based devices. This common platform has applications and advantages as linear Frequency Discriminator device for phase modulated direct-detection Microwave Photonic Link, and as linear Electric Field Modulator for multilevel coherent transmitter.
- Phoenix Software organized the annual training software workshop at their premises in Enschede, the Netherlands between 22nd– 26th February 2016. In this event and within the frames of COMANDER, two posters about RAU chip design and portability were presented by COMANDER fellows. Four COMANDER secondees attended this event.
- A 2-day training workshop was organized at AUTH premises by Lumerical about Lumerical’s suite of products by working through some application examples of current industrial and academic interest.



The following journal publications were generated during the COMANDER project:

- G. Dabos, J. Bolten, A. Prinzen, A.-L. Giesecke, N. Pleros and D. Tsiokos “Perfectly vertical and fully-etched SOI grating couplers for TM polarization”, Optics Communications, vol. 350, pp. 124-127, Jul 2015
- C. Vagionas, S. Pitris, C. Mitsolidou, J. Bos, P. Maniotis, D. Tsiokos and N. Pleros, “All-Optical Tag Comparison for Hit/Miss Decision in Optical Cache Memories”, IEEE Photonics Technol. Lett., vol. 28, no. 7, Apr. 2016
- G. Kalfas, N. Pleros, L. Alonso and C. Verikoukis, “Network planning for 802.11ad and MT-MAC 60 GHz fiber-wireless gigabit wireless local area networks over passive optical networks”, IEEE/OSA Journal of Optical Communications and Networking, vol. 8, is. 4, Apr 2016
- C. Vagionas, C. Mitsolidou, D. Tsiokos, K. Ramantas, A. Miliou, and N. Pleros “Optical Physical-Layer Digital Network Coding for 2.5 Gb/s Fiber-Wireless Networks”, IEEE Photonics Technol. Lett., vol. 28, Is. 13, July 2016



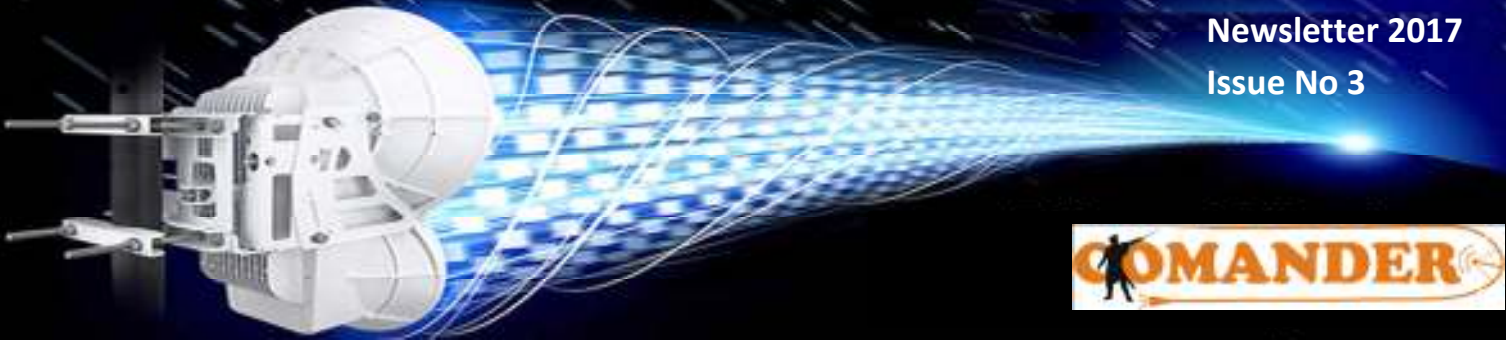
- T. Alexoudi, D. Fitsios, A. Bazin, P. Monnier, R. Raj, A. Miliou, G.T. Kanellos, N. Pleros and F. Raineri, "III-V-on-Si Photonic Crystal nanocavity laser technology for optical Static Random Access Memories (SRAMs)", IEEE Journal of Selected Topics on Quantum Electronics (JSTQE) special issue on Silicon Photonics, vol. 22, is. 6., aID 4901410, Nov-Dec.2016
- C. Mitsolidou, C. Vagionas, K. Ramantas, D. Tsiokos, A. Miliou and N. Pleros "Digital Optical Physical-Layer Network Coding for mm-wave Radio-over-Fiber signals", IEEE/OSA Journal of Lightwave Technology VOL. 34, NO. 20, OCTOBER 15, 2016
- S. Pitris, C. Vagionas, P. Maniotis, G.T. Kanellos and N. Pleros, An Optical Content Addressable Memory Cell for Address Look-Up at 10 Gb/s, IEEE Photonics Technol. Lett., Aug. 2016
- J. Mu, T. Alexoudi, Y. S. Yong, S. A. Vázquez-Córdova, M. Dijkstra, K. Wörhoff, J. Duis, and S. M. García-Blanco, "Low-loss highly tolerant flip-chip couplers for hybrid integration of Si₃N₄ and polymer waveguides", IEEE Photonics Technol. Lett., vol. 28, is. 3, pp.2748-2751, Oct-16
- P. Maniotis, S. Gitzenis, L. Tassioulas, N. Pleros, "An optically-enabled chip-multiprocessor architecture using a single-level shared optical cache memory", Journal of Optical Switching and Networking, vol. 22, pp. 54-68 Nov 2016
- C. Vagionas, P. Maniotis, S. Pitris, A. Miliou, N. Pleros, "Integrated Optical Content Addressable Memories (CAM) and Optical Random Access Memories (RAM) for Ultra-Fast Address Look-Up Operations", Applied Sciences, Vol. 7 Issue 7, p1-18, Jul-17
- C. Mitsolidou, N. Pleros and A. Miliou, "Digital All-Optical Physical-Layer Network Coding for 2Gbaud DQPSK Signals in mm-Wave Radio-over-Fiber Networks", Optical Switching and Networking Journal, submitted.

Two book chapters were published during the COMANDER project

- C. Vagionas, J. Bos, G.T. Kanellos, N. Pleros, A. Miliou, "Efficient and validated time domain numerical modelling of Semiconductor Optical Amplifiers (SOAs) and SOA-based circuits" INTECH Book Chapter in "Optical Amplifiers", Dec. 2015
- T. Alexoudi, G.T. Kanellos, S. Dris, D. Kalavrouziotis, P. Bakopoulos, A. Miliou and N. Pleros, "Semiconductor Optical Amplifier (SOA)-based amplification of intensity modulated optical pulses: Deterministic timing jitter and pulse peak power equalization analysis" INTECH Book Chapter in "Optical Amplifiers", Dec-15

Seven invited talks were given at related conferences regarding the COMANDER technologies, in addition to 24 contributed conference proceedings (the complete publication list can be found online at the project website <http://mc-comander.eu/>):

- A. Miliou, D. Tsiokos, Ch. Mitsolidou, G. Kalfas, N. Pleros, "Heterogeneous 60 GHz/ 5 GHz Broadband optical Wireless Systems supporting Dynamic Bandwidth Allocation", 16th International Conference on Transparent Optical Networks (ICTON) 2014, Jul-14, Graz, Austria
- G. T. Kanellos, Th. Alexoudi, D. Fitsios, P. Maniotis, C. Vagionas, N. Pleros, "Optical RAM-enabled cache memory and optical routing for chip multiprocessors", 20th Microoptics Conference (MOC'15), Oct. 25-28, 2015, Fukuoka, Japan



- D. Tsiokos, Ch. Mitsolidou, C. Vagionas, G. Kalfas, A. Miliou, N. Pleros, "*Converged Optical-Wireless Access Networks Enabling Fixed and 60 GHz Connectivity in WDM-PONs*", International Conference on Transparent Optical Networks (ICTON) 2016, 10-14 July 2016, Trento, Italy
- M. A. Sefunc, T. Alexoudi, J. Mu, M. Dijkstra, S. M. García-Blanco, "*Fabrication of high-contrast waveguide amplifiers in erbium doped potassium double tungstates*", 18th International Conference on Transparent Optical Networks (ICTON 2016), Jul-16, Trento, Italy
- N. Pleros, S. Pitris, C. Vagionas, P. Maniotis, T. Alexoudi, A. Miliou and G.T. Kanellos, "*Optical interconnect and memory technologies for next generation computing*" 18th International Conference on Transparent Optical Networks (ICTON 2016), Jul-16, Trento, Italy
- N. Pleros, G. Kalfas, C. Mitsolidou, C. Vagionas, D. Tsiokos and A. Miliou, "*High-Throughput and Low-Latency 60GHz small-cell network architectures over Radio-over-Fiber technologies*" SPIE Photonics West 2017 Feb-17 San Francisco, CA, USA
- G. Kalfas, J. Vardakas, L. Alonso, Ch. Verikoukis, N. Pleros, "*Medium Transparent MAC access schemes for seamless packetized fronthaul in mm-wave 5G picocellular networks*", International Conference on Transparent Optical Networks (ICTON) 2017", 3-6 July 2017, Girona, Spain

Secondments

Several secondments have commenced and continued during the third and fourth year of COMANDER. Within the course of the COMANDER project, an overall count of 20 researchers were seconded between the partners for a cumulative period of 261.5 months, achieving a fruitful exchange of knowledge and a harmonic partner collaboration. The invaluable collaboration and complementary expertise of the partners extended beyond the COMANDER project creating a long-lasting collaboration that led in the synthesis of two new successfully EU-funded projects (i) ICT-2016-2, "5G-PHOS- 5G integrated Fiber-Wireless networks exploiting existing photonic technologies for high-density SDN-programmable network architectures" and (ii) Marie-Curie Innovative Training Network (ITN) "5G STEP FWD-5G System Technological Enhancements Provided by Fiber Wireless Deployments" that will evolve the work done in COMANDER even further.