Grant Agreement number: 317762
Project acronym: COMBO
Project title: COnvergence of fixed and Mobile BrOadband access/aggregation networks
Funding Scheme: Collaborative Project – Integrated Project
Date of latest version of the Deliverable D7.3: 30 September 2016
Delivery Date: Month 45

Leader of the Deliverable: DTAG
File Name: COMBO_D7.3.1_WP7_30September2016_JCP_v1.0.docx
Version: 1.0
Authorisation code: PU = Public

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Executive Summary of the Deliverable

During the project lifetime, the COMBO project has generated a variety of knowledge, which was further disseminated via a number of measures. The project results have reached the wider community via different channels: printed materials, press releases, events, publications, standardization organizations, educational materials and eventually large scale demonstration event.

The most important numbers, which can characterize COMBO output, are as follows:

- Demonstration day, where COMBO outcomes were extensively demonstrated to external public in continuously running 5 booths;
- 4 comprehensive videos taken at demonstration day freely available on COMBO website;
- 67 accepted papers at conferences;
- 14 journal papers, including 6 invited ones;
- (19 papers among two above are done in collaboration – either internal (i.e. several Partners of the Consortium), or external);
- 15 invited papers at conferences;
- An invited FSAN paper on NG-PON2 for JOCN journal was co-authored by COMBO;
- Invitation to FSAN workshop for presentation of COMBO results on integration of fronthaul and backhaul with fixed access;
- 3 keynotes at conferences;
- Organized 4 workshops and gave 25 presentations at workshops/panels;

COMBO has produced an extensive tutorial on Fixed-Mobile Convergence and published it for free access on its website, co-edited a book for Springer “Optical networks” series, included its findings into academia courses (including governmental online education courses) and conducted numerous webinars.

Finally, COMBO being officially selected as feeding project for starting 5G-PPP projects, has fed those and also other FP7/H2020 project with its findings.
List of authors

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Approval

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<td>30.09.2016</td>
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<td>14.09.2016</td>
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<td>JOCN top downloads information added</td>
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<tr>
<td>0.6</td>
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<td>R. Kaurson</td>
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<tr>
<td>0.7</td>
<td>23.09.2016</td>
<td>Section on industrial collaboration added, collaboration with other initiatives and joint papers section updated. Executive summary, introduction and conclusion updated. Review ready version.</td>
<td>R. Kaurson</td>
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<td>A. Autenrieth</td>
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<td>27.09.2016</td>
<td>Section on Springer book updated</td>
<td>M. Tornatore</td>
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<td>0.10</td>
<td>29.09.2016</td>
<td>Section on smaller-scale demonstrations added</td>
<td>P. Olasz</td>
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<tr>
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<td>29.09.2016</td>
<td>Integration of review comments, revision of document, final formatting.</td>
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## Glossary

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<th>Brief description</th>
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<tr>
<td>3GPP</td>
<td>3rd Generation Partnership Project</td>
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<tr>
<td>5G-PPP</td>
<td>The 5G Infrastructure Public Private Partnership</td>
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<td>AMCC</td>
<td>Auxiliary Management and Communications Channel</td>
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<td>BBF</td>
<td>Broadband Forum</td>
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<td>BBU</td>
<td>Baseband Unit</td>
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<td>CoMP</td>
<td>Coordinated Multipoint</td>
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<tr>
<td>C-RAN</td>
<td>Cloud Radio Access Network</td>
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<tr>
<td>DSL</td>
<td>Digital Subscriber Line</td>
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<tr>
<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
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<tr>
<td>Fi-Wi</td>
<td>Fiber-Wireless</td>
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<td>FMC</td>
<td>Fixed-Mobile Converged Network</td>
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<td>FSAN</td>
<td>Full Service Access Network</td>
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<tr>
<td>HetNet</td>
<td>Heterogeneous network</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<td>IETF</td>
<td>Internet Engineering Task Force</td>
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<td>IRTF</td>
<td>Internet Research Task</td>
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<tr>
<td>ISG</td>
<td>Industry Specification Group</td>
</tr>
<tr>
<td>ITU-T</td>
<td>International Telecommunication Union – Telecommunication Standardization Sector</td>
</tr>
<tr>
<td>JOCN</td>
<td>Journal of Optical Communications and Networking</td>
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<tr>
<td>LTE</td>
<td>Long Term Evolution</td>
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<tr>
<td>MEF</td>
<td>Metro Ethernet Forum</td>
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<td>NGMN</td>
<td>Next Generation Mobile Networks Alliance</td>
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<tr>
<td>NG-PON2</td>
<td>40-Gigabit-capable Passive Optical Network</td>
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<tr>
<td>NG-PoP</td>
<td>Next Generation Point of Presence</td>
</tr>
<tr>
<td>OAM</td>
<td>Operations, Administration and Management</td>
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<tr>
<td>ODN</td>
<td>Optical Distribution Network</td>
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<td>OMA</td>
<td>Open Mobile Alliance</td>
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<tr>
<td>ONU</td>
<td>Optical Network Unit</td>
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<tr>
<td>PHY</td>
<td>physical layer</td>
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<tr>
<td>PON</td>
<td>Passive Optical Network</td>
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<tr>
<td>PIP</td>
<td>Point-to-Point</td>
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<tr>
<td>RAN</td>
<td>Radio Access Network</td>
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<tr>
<td>SDO</td>
<td>Standard Definition Organization</td>
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<tr>
<td>TWDM</td>
<td>Time and Wavelength Division Multiplexed</td>
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<tr>
<td>UAG</td>
<td>Universal Access Gateway</td>
</tr>
<tr>
<td>WBA</td>
<td>Wireless Broadband Alliance</td>
</tr>
<tr>
<td>WDM</td>
<td>Wavelength-division multiplexing</td>
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<tr>
<td>WP</td>
<td>Workpackage or White Paper</td>
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<td>WR</td>
<td>Wavelength-Routed</td>
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1 Introduction

This document describes the dissemination and collaboration activities performed by the COMBO project from its beginning (January 2013) until the end of the project (September 2016). This document is the first and public part of deliverable D7.3 (Final report on dissemination and Exploitation).

The dissemination activities in the project were conducted according to general principles, described in the deliverable D7.1 [1]. Thus, this document describes a broad set of the activities that were planned and implemented. These activities mainly include:

- Creation of dissemination package (visual material that supports other activities), such as poster, leaflet, website, several project presentations;
- Publications at various high-level international conferences and journals;
- Presentation of the project and its results at workshops;
- Collaboration with other related FP7/H2020 projects and
- Collaboration with upcoming new 5G-PPP projects.
- Demonstration of project outcomes and dissemination of relevant materials.

In the next chapters all dissemination activities are categorized and reported more precisely.
1 Project presentation material

1.1 Website

The website of the COMBO project ([http://ict-combo.eu/](http://ict-combo.eu/)) has a simple structure for ease of navigation. Home page is exposing main menu items (horizontal bar), latest news, upcoming events and short description of the project itself.

![COMBO website screenshot](image)

Figure 1 – COMBO website screenshot

The horizontal menu presents the main body of the website, and proposes the following categories:

- **HOME** (return to the home page);
- **ABOUT** (project description);
- **DELIVERABLES** (deliverables of the project);
- **DISSEMINATION** (project scientific and technical output);
- **FMC TUTORIAL** (comprehensive collection of videos and slides related to FMC prepared and recorded on one of the events);
- UAG WP (White Paper describing the Universal Access Gateway as a key concept in Fixed Mobile Convergence vision of the COMBO project);

- DEMO RESULTS (full description of the project demonstration event that took place in April 2016 in Lannion (France)).

1.2 Printed material

1.2.1 Poster

COMBO project has designed two versions of its poster: the first one when the project had started, and the second one in 2015, with the appearance of several particular results.

The first poster, exhibited below, describes the project objectives and expected impact, as well as briefly describing the NG-PoP concept.

![Initial version of COMBO poster](image-url)
The next revision of the poster started in the spring of 2015 and resulted in carefully elaborated, clean-slate and eye-catching work, presenting “Fixed mobile network integration” (and not the name of the project) as a highlighted slogan, or topic. The poster presents motivation, objectives and benefits of such integration, explains underlying concepts of structural and functional convergence and reports on key outcomes. The poster is exhibited below:

**FIXED MOBILE NETWORK INTEGRATION**

**Motivation**
- Deal with increasing traffic and changing applications
- Adopt network structure and integrate fixed and mobile infrastructures
- Improve placement of intelligence in the network
- Enableopen environment for fixed and mobile networks

**Objectives**
- Define and develop Fixed Mobile Converged (FMC) architectures for future networks
- Demonstrate experimentally key FMC network features
- Influence standardization bodies with regard to FMC architectures

**Benefits**
- Unify hardware resources
- Save cost and energy
- Simplify network architectures
- Improve network operation and user experience
- Enable a 5G infrastructure with end-to-end management and orchestration capabilities

**COMBO concepts and results**

**Structural convergence / Streamlining of transport**
- Structural convergence is defined as pooling/sharing of network and infrastructure resources for fixed, mobile and Wi-Fi
- Structural convergence will be triggered by heterogeneous RANs, mobile fractional and centralized RAN
- A unified critical access / aggregation network with low latency and high capacity will foster structural convergence

**Functional convergence / Universal Access Gateway**
- Functional convergence is the implementation of generic functions to realize similar goals in fixed, mobile and Wi-Fi. It will rely on:
  - Universal Authentication (UAA)
  - Universal Data Path Management (UDP)
  - Universal Access Gateway (UAG) as a common subscriber IP edge

**Key outcomes**

**Streamlining of transport**

![Figure 3 – Revised version of COMBO poster](image-url)
1.2.2 Leaflet

Similarly to the poster, two rounds of creation of leaflets happened in COMBO.

In the early beginning of the project, an A4 leaflet and three-fold brochure were produced, describing objectives, technical approach and NG-PoP concept, as well as expected impacts. This is exposed in the figure below.

![Initial version of the COMBO project leaflet](image-url)
Similarly to the poster, a clean-slate approach to leaflet design was undertaken in spring 2015. A new version of the leaflet was issued in parallel with the poster and was similar in style and information on it, which can be seen below:
Figure 6 – revised version of three-fold leaflet of COMBO project
2 Dissemination activities performed during project lifetime

2.1 Introduction

The dissemination activities in COMBO are divided into several groups for ease of categorization and navigation – for both the consortium and for the external viewer who is interested in scientific and technical outcomes of the project. Those groups are:

- Peer-reviewed technical papers in international conferences;
- Invited technical papers in conferences;
- Technical papers in international journals or magazines - whereas two subcategories exist for this group, which are:
  - Peer-reviewed technical papers in international journals or magazines;
  - Invited technical papers in international journals or magazines;
- Keynote speeches at international conferences;
- Presentations at workshops or panels.

Last, but not least – several activities performed by the COMBO project cannot be categorized under any of the groups shown above, however having significant dissemination importance. Undoubtedly, one of these activities is the demonstration of the project outcomes – and this is especially valid for the final period of the project. A separate chapter of the following description is specifically dedicated to the description of demonstration activities.

In addition to the categorization of types of dissemination activities, the latter are also divided into several technical areas, which were tentatively formulated by the Consortium as follows:

- A - FMC Network architectures & NG-PoP concept
- B - Energy efficiency and green benefit of FMC
- C - RAN design enabling FMC
- D - Traffic engineering for FMC
- E - Optical Access Network design for FMC

The following chapters also briefly describe areas, where COMBO contribution is most significant.
2.2 Demonstration of COMBO concepts and related dissemination

Main outcomes and proofs of concept of the COMBO project were showcased during a demo event, which took place on 28th April 2016 at Pôle Images & Réseaux premises in Lannion, France. It was defined to organize different demo booths which aimed at showcasing the attained FMC solutions to the public, which eventually gathered around 40 external visitors.

![Demo Invitation](image)

Figure 7 – Lannion demo invitation

As mentioned, the demonstrations were organized in five booths that were running five times a day for one hour each:

- COMBO Architectural Concepts and Outcomes
- Distributed NG-POP
- Centralized / Distributed NG-POP
- Universal Authentication and Data Path Management
- Universal Data Path Management and Caching

The demonstration featured improved multi-access user experience enabled by advanced virtualized network functions. The Demo event fully reached its technical and dissemination objectives with fruitful experimental results. The various booths shown at this demo event have also been video-recorded, so as to allow further...
dissemination of COMBO experimental outcomes and vision on integration of fixed and mobile networks for 5G architecture.

Figure 8 – At the booth during COMBO demonstration day

Figure 9 – On of the booths, equipment for COMBO demonstration day

Post-processed videos of the demo event and overall description of demonstration are available on the COMBO website.

1 http://www.ict-combo.eu/index.php?id=combo-demo-results
2.3 Peer-reviewed technical papers in international conferences

This category is the largest one for dissemination of COMBO results, with a total of 67 accepted papers. They were presented in a wide variety of high-level international conferences – which vary from large “heavyweighter” events, such as OFC/NFOEC, ICC and ECOC to smaller scale specialized (mostly Europe-wide) conferences, such as EuCNC, European Wireless and HPSR.

Among technical areas, “A - FMC Network architectures & NG-PoP concept” was the first publication topic (26 papers), followed by “E - Optical Access Network design for FMC”, “D - Traffic engineering for FMC” and “C - RAN design enabling FMC” (17, 12 and 12 papers respectively). 7 publications covered “B - Energy efficiency and green benefit of FMC”. Note that several papers were on technical topics across several areas.

Both academic and industrial partners, including SMEs were active in this traditional dissemination activity and it also should be noted that several papers were the result of a joint work of several organizations – either belonging to the COMBO consortium, or even outside. The current chapter, however, describes all peer-reviewed technical papers in total, whereas a selection of collaborative publications is given explicitly in chapter 2.11.

The table below presents all mentioned technical publications in chronological order:
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<th>Author(s)</th>
<th>Title</th>
<th>Period</th>
<th>Place</th>
<th>Type of audience</th>
<th>URL</th>
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</thead>
</table>

² Full list of authors is hidden for optimum space usage. Full list of authors for this publication is Philippe CHANCLOU, Anna PIZZINAT, Fabien LE CLECH, To-Linh REEDEKER, Yannick LAGADEC, Fabienne SALIU, Bertrand LE GUYADER, Laurent GUILLO, Qian DENIEL, Stéphane GOSSELIN, Sy Dat LE, Thierno DIALLO, Romain BRENOT, Francois LELARGE, Lucia MARAZZI, Paola PAROLARI, Mario MARTINELLI, Sean O’DULL, Simon Arega GEBREWOLD, David HILLERKUSS, Juerg LEUTHOLD, Giancarlo GAVIOLI, Paola GALLI
8. **IEEE GreenCom 2013**  
   P. Dini, M. Miozzo, N. Bui, N. Baldo  
   Model to Analyze the Energy Savings of Base Station Sleep Mode in LTE HetNets  
   Aug-13  
   Beijing, China  
   Industry + academic  
   [Link](http://www.cttc.es/publication/a-model-to-analyze-the-energy-savings-of-base-station-sleep-mode-in-lte-hetnets/)

9. **ECOC 2013**  
   R. Martinez, R. Casellas, R. Muñoz, R. Vilalta  
   Experimental evaluation of delay-sensitive traffic routing in multi-layer (packet-optical) aggregation networks for fixed mobile convergence  
   Sep-13  
   London, UK  
   Industry + academic  

10. **ECOC 2013**  
    K. Grobe  
    Access Networks Based on Tunable Transmitters (Invited)  
    Sep-13  
    London, UK  
    Industry + academic  
    [Link](http://dx.doi.org/10.1049/cp.2013.1403)

11. **IEEE ANTS 2013**  
    Pál Varga, Péter Olaszi  
    LTE core network testing using generated traffic based on models from real-life data  
    Dec-13  
    SRM Uni., India  
    Industry + academic  
    [Link](http://www.researchgate.net/publication/259464868_LTE_core_network_testing_using_generated_traffic_based_on_models_from_real-life_data)

12. **CogInfo Com 2013**  
    T. Cinkler, A. Ladanyi, R. Beres, A. Miltisenkov, G. Paksy, B. Molnar, R. Ando  
    Energy-Availability-QoS Trade-off for Future Converged Fixed-Mobile Networks  
    Dec-13  
    Budapest, Hungary  
    Academic  
    [Link](http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6719305)

13. **CCSCI 2014**  
    M. Feknoun, B. Le Guyader, and A. Gravey  
    Revisiting Access and Aggregation Network Architecture  
    Jan-14  
    Toronto, Canada  
    Industry + academic  
    [Link](https://portal.telecom-bretagne.eu/publi/public/fic_download.jsp?id=21164)

14. **OFC/NFOEC 2014**  
    Annie Gravey, Philippe Gravey, Michel Morvan, Bogdan Uscumlic, Lida Sadeghiou  
    QoS of Optical Packet Metro networks  
    Mar-14  
    San Francisco California, USA  
    Industry + academic  
    [Link](https://portal.telecom-bretagne.eu/publi/public/fic_download.jsp?id=21167)

15. **NMTS2014**  
    Giacomo Verticale,  
    On the Tradeoff between Performance and User Privacy in Information Centric Networking  
    Mar-14  
    Dubai, UAE  
    Industry + academic  
    [Link](http://goo.gl/IApNK4)
| 16 | OFC/NFOEC 2014 | Diallo, Thierno; Pizzinat, Anna; Chanclou, Philippe; Saliou, Fabienne; Deletre, Fabrice; Aupetit-Berthelemot, Christelle | Jitter impact on mobile fronthaul links | Mar-14 | San Francisco California, USA | Industry + academic | http://www.opticsinfobase.org/abstract.cfm?URI=OFC-2014-W2A.41 |

<table>
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<tr>
<th>No.</th>
<th>Event Year</th>
<th>Authors</th>
<th>Title</th>
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<tr>
<td>24</td>
<td>ONDM 2014</td>
<td>Ahmed Triki, Ramon Aparicio-Pardo, Paulette Gavignet, Esther Le Rouzic, B. Arzur, A. Gravey</td>
<td>Is It Worth Adapting Sub-Wavelength Switching Control Plane to Traffic Variations</td>
</tr>
<tr>
<td>26</td>
<td>ISCC2014</td>
<td>M. Feknous, T. Houdoin, B. Le Guyader, J. De Biasio, A. Gravey, Jose Torrijos</td>
<td>Internet Traffic Analysis: A Case Study From Two Major European Operators</td>
</tr>
<tr>
<td>28</td>
<td>ICTON 2014</td>
<td>József Czékus, Péter Megyesi, Attila Mitcsenkov, Daniel Mazroa</td>
<td>Hardware Cost and Capacity Analysis of Future TDM- and WDM-PON Access Networks</td>
</tr>
<tr>
<td>29</td>
<td>Networks 2014</td>
<td>Anna Buttaboni, Marilet De Andrade, Massimo Tornatore</td>
<td>Dynamic Bandwidth and Wavelength Allocation with Coexistence of Transmission Technologies in TWDM PONs</td>
</tr>
<tr>
<td>30</td>
<td>ECOC 2014</td>
<td>M. Tomatore</td>
<td>An Energy Consumption Comparison of Different Mobile Backhaul and Fronthaul Optical Access Architectures</td>
</tr>
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<td>32</td>
<td>Eunice 2014</td>
<td>Souheir Eido, Annie Gravey</td>
<td>How much LTE traffic can be offloaded?</td>
</tr>
<tr>
<td>No.</td>
<td>Event</td>
<td>Authors</td>
<td>Title</td>
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</tr>
<tr>
<td>38</td>
<td>IEEE Cloudnet conference</td>
<td>Mariet De Andrade, Massimo Tornatore, Achille Pattavina, Ali Hamidian, Klaus Grobe</td>
<td>Cost Models for Baseband Unit (BBU) Hotelling: from Local to Cloud</td>
</tr>
<tr>
<td>No.</td>
<td>Conference</td>
<td>Authors</td>
<td>Title</td>
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</tbody>
</table>

4 Full list of authors is hidden for optimum space usage. Full list of authors for this publication is Thierno Diallo, Bertrand Le Guyader, Anna Pizzinat, Stéphane Gosselin, Philippe Chanclou, Fabienne Saliou, Amr Abdel fattath, Christelle Aupetit-Berthelemot
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<th>No.</th>
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<th>Title</th>
<th>Authors</th>
<th>Date</th>
<th>Location</th>
<th>Type of Requirments</th>
<th>URL</th>
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<tr>
<td>49</td>
<td>ECOC 2015</td>
<td>Experimental Validation of a SDN Orchestrator for the Automatic Provisioning of Fixed and Mobile Services</td>
<td>Ricardo Martinez, Ricard Vilalta, Ramon Casellas, Raul</td>
<td>Sep-15</td>
<td>Valencia, Spain</td>
<td>Industry + academic</td>
<td><a href="http://goo.gl/yWhGR4">http://goo.gl/yWhGR4</a></td>
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<tr>
<td>54</td>
<td>CCNC 2016</td>
<td>Performance analysis of LTE-WiFi very tight coupling</td>
<td>Y. Khadraoui, X. Lagrange, A. Gravey</td>
<td>Jan-16</td>
<td>Las Vegas, US</td>
<td>Industry+ Academic</td>
<td>Not yet available</td>
</tr>
<tr>
<td>No.</td>
<td>Conference</td>
<td>Authors</td>
<td>Title</td>
<td>Location</td>
<td>Date</td>
<td>Industry Status</td>
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</tr>
<tr>
<td>58</td>
<td>WD-16</td>
<td>Younes Khadraoui, Xavier Lagrange, Annie Gravey</td>
<td>Very Tight Coupling Between LTE and WiFi: From Theory To Practice</td>
<td>Mar-16</td>
<td>Toulouse</td>
<td>Industry+ Academic</td>
<td>Not yet available</td>
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<tr>
<td>60</td>
<td>EuCNC 2016</td>
<td>Ricard Vilalta, Arturo Mayoral, Ramon Casellas, Ricardo Martinez, Raul Muñoz</td>
<td>Experimental demonstration of distributed multi-tenant cloud/fog and heterogeneous SDN/NFV orchestration for 5G services</td>
<td>Jun-16</td>
<td>Athens, Greece</td>
<td>Industry + academic</td>
<td>Not yet available</td>
</tr>
<tr>
<td>61</td>
<td>ICTON 2016</td>
<td>Marco Savi, Ali Hmaitly, Giacomo Verticale, Stefan Höst, Massimo Tornatore</td>
<td>To Distribute or Not to Distribute? Impact of Latency on Virtual Network Function Distribution at the Edge of FMC Networks</td>
<td>Jul-16</td>
<td>Trento, Italy</td>
<td>Industry + academic</td>
<td>Not yet available</td>
</tr>
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</table>
2.4 Invited technical papers in conferences

COMBO produced 15 invited papers and this comprises both bigger (OFC/NFOEC, LTE World Summit, ECOC) and smaller scale conferences (ONDM, HPSR, ICTON) – which shows significant demand towards FMC concepts from industry and academia. Papers were presented mostly by industrial Partners (Orange, DTAG, TID, ADVA) with a few ones presented by AITIA and POLIMI.

Among technical areas, “C - RAN design enabling FMC” was the most demanded one with 8 papers, followed by “A - FMC Network architectures & NG-PoP concept” and “E - Optical Access Network design for FMC” with 5 papers for both categories (some of papers for cross-topic). The following table reports on invited conference papers in details:

<table>
<thead>
<tr>
<th>No.</th>
<th>Conference</th>
<th>Authors</th>
<th>Title</th>
<th>Date</th>
<th>Location</th>
<th>Industry/Academic</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>64</td>
<td>EOC 2016</td>
<td>Francesco Musumeci, Massimo Tornatore, Achille Pattavina</td>
<td>A Techno-Economic Outlook to Optical-Interface Requirements for Midhauling of 5G Small Cells</td>
<td>Sep-16</td>
<td>Düsseldorf, Germany</td>
<td>Industry + academic</td>
<td>Not yet available</td>
</tr>
<tr>
<td>65</td>
<td>VTC-16 Fall</td>
<td>Younes Khadraoui, Xavier Lagrange, Annie Gravey</td>
<td>TCP performance for practical implementation of very tight coupling between LTE and WiFi</td>
<td>Sep-16</td>
<td>Montreal</td>
<td>Industry + Academic</td>
<td>Not yet available</td>
</tr>
<tr>
<td>66</td>
<td>SoftCom2016</td>
<td>Stefan Höst, William Tärneberg, Per Ödling, Maria Kihl, Marco Savi, Massimo Tornatore</td>
<td>Network Requirements for Latency-Critical Services in a Full Cloud Deployment</td>
<td>Sep-16</td>
<td>Split, Croatia</td>
<td>Industry + academia</td>
<td>Not yet available</td>
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<tr>
<td>67</td>
<td>SoftCom 2016</td>
<td>Stefan Höst, William Tärneberg, Per Ödling, Maria Kihl, Marco Savi, Massimo Tornatore</td>
<td>Network Requirements for Latency-Critical Services in a Full Cloud Deployment</td>
<td>Sep-16</td>
<td>Split, Croatia</td>
<td>Academic / Industry</td>
<td>Not yet available</td>
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Table 1 - Peer-reviewed technical papers in international conferences
<table>
<thead>
<tr>
<th>№</th>
<th>Name of event</th>
<th>Author(s)</th>
<th>Title</th>
<th>Period</th>
<th>Place</th>
<th>Type of audience</th>
<th>URL to publisher</th>
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<tr>
<td>1</td>
<td>LTE World Summit’13</td>
<td>Anna Pizzinat</td>
<td>C-RAN architecture and fronthaul challenges</td>
<td>Jun-13</td>
<td>Amsterdam, Netherlands</td>
<td>Industry + academic</td>
<td><a href="http://www.lteconference.com/world">www.lteconference.com/world</a></td>
</tr>
<tr>
<td>4</td>
<td>ECOC 2014</td>
<td>Anna Pizzinat</td>
<td>Things you should know about fronthaul</td>
<td>Sep-14</td>
<td>Cannes, France</td>
<td>Industry + academic</td>
<td><a href="http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&amp;arnumber=6964214">http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&amp;arnumber=6964214</a></td>
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<tr>
<td>5</td>
<td>Broadband World Forum 2014</td>
<td>Anna Pizzinat</td>
<td>What is the architecture of future connectivity</td>
<td>Oct-14</td>
<td>Amsterdam, Netherlands</td>
<td>Industry + academic</td>
<td><a href="http://www.broadbandworldforum.com">www.broadbandworldforum.com</a></td>
</tr>
<tr>
<td>7</td>
<td>ONDM 2015</td>
<td>S. Pachnicke, M. Eiselt, K. Grobe J.-P. Elberns</td>
<td>The Frontiers of Optical Access Networks</td>
<td>May-15</td>
<td>Conference, Pisa, Italy</td>
<td>Industry + academic</td>
<td><a href="http://dx.doi.org/10.1109/ONDM.2015.7127266">http://dx.doi.org/10.1109/ONDM.2015.7127266</a></td>
</tr>
</tbody>
</table>

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5 Full list of authors is hidden for optimum space usage. Full list of authors for this publication is Stéphane Gosselin, Anna Pizzinat, Xavier Grall, Dirk Breuer, Eckard Bogenfeld, Jose Torrijos Gijón, Ali Hamidian, Neiva Fonseca
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<th></th>
<th>Conference</th>
<th>Title</th>
<th>Authors</th>
<th>Date</th>
<th>Location</th>
<th>Sector</th>
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<tbody>
<tr>
<td>15</td>
<td>ICTON 2016</td>
<td>Assessment of Fixed Mobile Converged Backhaul and Fronthaul Networks</td>
<td>Erik Weis, Dirk Breuer, Sandro Krauß</td>
<td>Jul-16</td>
<td>Trento, Italy</td>
<td>Industry + academic</td>
<td>Not yet available</td>
</tr>
</tbody>
</table>

Table 2 - Invited technical papers in conferences

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6 Full list of authors is hidden for optimum space usage. Full list of authors for this publication is Péter Olaszi, Dirk Breuer, Tibor Cinkler, Stéphane Gosselin, Annie Gravey, Ali Hamidian, Stefan Höst, Tahar Mamouni, Stephan Pachnicke, Björn Skubic, Jose Torrijos Gijón
2.5 Technical papers in international journals or magazines

Altogether, the COMBO project has published 14 journal papers on a variety of FMC-related topics. As already mentioned, an additional two sub-divisions are introduced for the group of journal papers. The following sub-chapters describe those.

2.5.1 Peer-reviewed technical papers in international journals or magazines

From the above mentioned 14 journal papers, 8 papers are regular peer-reviewed journal papers, which are reporting on “A - FMC Network architectures & NG-PoP concept” (3 papers), “E - Optical Access Network design for FMC” (2 papers), “B - Energy efficiency and green benefit of FMC” (2 papers) and “D - Traffic engineering for FMC” (1 paper).

<table>
<thead>
<tr>
<th>№</th>
<th>Name of journal</th>
<th>Author(s)</th>
<th>Title</th>
<th>Period</th>
<th>URL to publisher</th>
</tr>
</thead>
</table>
2.5.2 Invited technical papers in international journals or magazines

Moreover, COMBO was invited to publish 6 journal papers (among which 4 are published and 2 are awaiting for publication). Partners Orange, ADVA, POLIMI and EAB were involved in this activity, which is described in the table below:

|----|---------------------------------------------------|---------------------------------------------------------------------------------|-----------------------------------------------------------------------|--------|-----------------------------------------------------------------------------|

Table 3 - Peer-reviewed technical papers in international journals or magazines
<table>
<thead>
<tr>
<th>No.</th>
<th>Journal/Conference Name</th>
<th>Authors</th>
<th>Title</th>
<th>Publication Date</th>
<th>URL</th>
</tr>
</thead>
</table>

Table 4 - Invited technical papers in international journals or magazines
2.5.3 Invited FSAN JOCN 2-part paper on NG-PON2

In the beginning of 2016, the Journal of Optical Communications and Networking (JOCN) has issued a 2-part invited FSAN paper on Physical Layer Aspects of NG-PON2 Standards [2]. This paper is not sole outcome of the COMBO project, however was co-authored by one of COMBO Consortium Partners (Klaus Grobe, ADVA) and thus was partly influenced by the COMBO outcomes.

2.5.3.1 Part 1: Optical Link Design

Authors: Jun Shan Wey, Joe Smith, Yuanqiu Luo, Derek Nesset, Klaus Grobe, Hal Roberts, Maurizio Valvo

Abstract—The physical layer specification of the 40-Gigabit-capable Passive Optical Networks (NG-PON2), recently approved by the ITU-T as the G.989.2 Recommendation, is the result of over three years of collaborative work by members of the FSAN and ITU-T Q2/SG15 groups. It is the industry's first set of multi-wavelength based PON standard. This two-part paper provides the technical insight and development rationales of the approved standard, as the authors were part of the core team during the standards development process. This first part of the paper focuses on optical link design topics, including the optical distribution network, Raman crosstalk related degradation, and inter-channel crosstalk tolerance. It also investigates the wavelength tuning capability of Optical Network Units (ONUs) and its impact on the physical layer specification.

Index Terms - Multiaccess communication; Optical fiber network; Passive Optical Network; Standards.

2.5.3.2 Part 2: Management, Control, and Technology Feasibility

Authors: Jun Shan Wey, Yuanqiu Luo, Joe Smith, Derek Nesset, Klaus Grobe, Hal Roberts, Maurizio Valvo, Harald Rohde, Kota Asaka, Frank Effenberger

Abstract—This paper is the second of a two-part contribution intended to provide technical insight and development rationale behind the recently approved ITU-T G.989.2 Recommendation: the physical layer specification of the 40-Gigabit-capable Passive Optical Networks (NG-PON2). While Part 1 of the contribution discusses topics related to the optical link design, Part 2 focuses on the design considerations of spectral excursion, as well as management, control, and technical feasibility of such multi-wavelength PON system. As NG-PON2 continues to evolve, technology extensions are also discussed to provide guidance to the industry for future research directions.

Index Terms - Multiaccess communication; Optical fiber networks; Passive Optical Network; Standards.
2.5.3.3 Aspects of influence FSAN/Q.2/G.989 – COMBO:

There are several aspects where influence between FSAN/Q.2/G.989 and the COMBO project have happened. This holds for both directions. It also holds for older (predecessor) projects like EU FP7 OASE, since NG-PON2 (G.989) started more than 5 years ago as a major long-term project. Meanwhile, first parts of the G.989 Series of Recommendations are in force, but work is ongoing since not everything is finalized already. Therefore, also in the future there are possibilities for influencing this Recommendation Series, which is today the most relevant standard with regard to (next-generation) access technologies suitable for FMC.

Influence from COMBO onto G.989 includes NG-PON2 support of fronthaul bit rates (which was in particular pushed by Orange), and the allowance of a dedicated expanded-spectrum PtP WDM PON variant (this work started already under the OASE project and was continued under COMBO). Meanwhile, this also led to FSAN/Q.2 considerations of wavelength-routed ODN (since this may have certain advantages in non-residential-access infrastructure deployments). As an illustration of COMBO influence to FSAN work, the main COMBO results on integration of fronthaul and backhaul with fixed access were presented at an FSAN workshop during the FSAN meeting in Atlanta in October 2015.

An aspect where influence also pointed in the other direction (toward COMBO) is the reduction of generic WDM-PON candidate systems solutions to those based on tunable lasers (the NG-PON2 choice). Further important work initially supported by COMBO (and before that OASE) refers to the G.989 AMCC, which is the transparent signalling channel which is necessary to activate new, remote ONUs in such a system. It has been brought into FSAN/Q.2 as a necessary feature, and similar functionality is used for COMBO infrastructure solutions.

Areas for future work on NG-PON2, supported by COMBO and potential successor projects, include reach extenders (because some of the COMBO infrastructure deployments require reach extensions), higher bit rates of the PtP WDM sub-system, and potentially the areas of OAM (monitoring) and also some further work on hybrid and WR-ODN and the related coexistence aspects.

It should be also mentioned, that both parts of these papers were in the JOCN top downloads in April 2016, as shown on Figure 10.
2.6 Keynote speeches at international conferences

COMBO has given 3 keynotes: one in 2013, one in 2014 and one in 2015. Those were:

<table>
<thead>
<tr>
<th>№</th>
<th>Name of event</th>
<th>Author(s)</th>
<th>Title</th>
<th>Period</th>
<th>Place</th>
<th>URL to publisher</th>
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</thead>
</table>

Table 5 - Keynote speeches at international conferences

2.7 Presentations at workshops or panels

COMBO was presented in a wide variety of workshops and panels, which included worldwide events with thousands of participants (like OFC/NFOEC and ECOC), smaller events, as well as some seminars. Altogether there were 25 activities to be mentioned under this category, whereas the majority of them (14) were presented in the area of "A - FMC Network architectures & NG-PoP concept". Table below shows that in details:
<table>
<thead>
<tr>
<th>№</th>
<th>Name of event</th>
<th>Author(s)</th>
<th>Title</th>
<th>Period</th>
<th>Place</th>
<th>Type of audience</th>
<th>URL to publisher</th>
</tr>
</thead>
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<tr>
<td>2</td>
<td>Seminar at University of California, Davis</td>
<td>M. Tornatore</td>
<td>The Role of Optical Networks in the Big Data Era</td>
<td>Apr-13</td>
<td>Davis, CA, USA</td>
<td>Academic</td>
<td><a href="http://seminars.cs.ucdavis.edu/?type=1&amp;when=past">http://seminars.cs.ucdavis.edu/?type=1&amp;when=past</a></td>
</tr>
<tr>
<td>4</td>
<td>FuNeMS 2013</td>
<td>D. Breuer, S. Gosselin, J. Torrijos, J.-C. Point</td>
<td>Challenges in mutualization of Fixed and Mobile networks</td>
<td>Jul-13</td>
<td>Lisbon, Portugal</td>
<td>Industry + academic</td>
<td>Not applicable</td>
</tr>
<tr>
<td>5</td>
<td>OFC/NFOEC 2014</td>
<td>Anna Pizzinat</td>
<td>How D-RoF has Established as the Natural Choice for Mobile Front-haul Transport;</td>
<td>Mar-14</td>
<td>San Francisc0 (CA)</td>
<td>Industry + academic</td>
<td>Not applicable</td>
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<tr>
<td>8</td>
<td>EuCNC 2014</td>
<td>Jean-Charles Point, Stefano Bregni, Achille Pattavina</td>
<td>Fixed-Mobile Convergent Networks: Solutions and Architectures Proposed in FP7</td>
<td>Jun-14</td>
<td>Bologna, Italy</td>
<td>Industry + academic</td>
<td>Not applicable</td>
</tr>
<tr>
<td>9</td>
<td>EuCNC 2014</td>
<td>Stephane Gosselin</td>
<td>COMBO – Network scenarios for Fixed Mobile Convergence</td>
<td>Jun-14</td>
<td>Bologna, Italy</td>
<td>Industry + academic</td>
<td>Not applicable</td>
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<tr>
<td>#</td>
<td>Event Details</td>
<td>Presenters</td>
<td>Topic/Details</td>
<td>Date</td>
<td>Location</td>
<td>Type</td>
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<td>11</td>
<td>Ericsson University Day 2016</td>
<td>Tibor Cinkler, Ákos Ladányi, Attila Mitcsenkov</td>
<td>5G MultiOperator Network Sharing Scenarios</td>
<td>May-15</td>
<td>Budapest, BME</td>
<td>Industry + academia</td>
<td>Not applicable</td>
</tr>
<tr>
<td>13</td>
<td>ECOC 2015</td>
<td>S. Pachnicke</td>
<td>NFV-based Universal Access for converged fixed and mobile broadband access/aggregation networks</td>
<td>Sep-15</td>
<td>Valencia, Spain</td>
<td>Industry + academic</td>
<td>Not applicable</td>
</tr>
<tr>
<td>14</td>
<td>RAN World 2015</td>
<td>Philippe Chanclou, Sébastien Randazzo</td>
<td>Changes, Challenges and Case studies in the fronthaul network for C-RANs</td>
<td>Sep-15</td>
<td>Cologne, Germany</td>
<td>Industry</td>
<td>Not applicable</td>
</tr>
<tr>
<td>15</td>
<td>FSAN Workshop 2015</td>
<td>Philippe Chanclou</td>
<td>Presentation of mobile evolution and impact on optical access network</td>
<td>Oct-15</td>
<td>Atlanta, USA</td>
<td>Industry</td>
<td>Not applicable</td>
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<tr>
<td>16</td>
<td>5G-Xhaul plenary meeting</td>
<td>J. Torrijos Gijon</td>
<td>COMBO presentation to 5G-XHAUL</td>
<td>Dec-15</td>
<td>Madrid, Spain</td>
<td>Industry + academic</td>
<td>Not applicable</td>
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<tr>
<td>17</td>
<td>MWC 2016</td>
<td>Ricard Vilalta, Arturo Mayoral, Ramon Casellas, Ricardo Martinez, Raúl Muñoz</td>
<td>Distributed multi-tenant cloud/fog and heterogeneous SDN/NFV orchestration for 5G services</td>
<td>Feb-16</td>
<td>Barcelona, Spain</td>
<td>Industry + Academic</td>
<td>Not applicable</td>
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<tr>
<td>18</td>
<td>5G-PPP Workshop on Architecture</td>
<td>S. Gosselin, B. Skubic</td>
<td>Experimental Real Time AMCC Implementation for Fronthaul in PiP WDM-PON</td>
<td>Apr-16</td>
<td>Brussels, Belgium</td>
<td>Industry + academic</td>
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<td>19</td>
<td>1st International Workshop on Elastic Networks Design and Optimisation (ELASTICNETS 2016)</td>
<td>Application of SDN-based orchestration for the automated deployment of fixed and mobile convergent services in future 5G networks</td>
<td>May-16</td>
<td>Cartagena, Spain</td>
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<tr>
<td>20</td>
<td>CORES</td>
<td>Very Tight Coupling between LTE and WiFi: a Practical Analysis</td>
<td>May-16</td>
<td>Bayonne, France</td>
<td>Industry+ Academic</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>EuCNC 2016</td>
<td>COMBO architectures for fixed and mobile network integration in 5G</td>
<td>Jun-16</td>
<td>Athens, Greece</td>
<td>Industry + academic</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>EuCNC 2016</td>
<td>Backhaul/Fronthaul for future 5G transport - COMBO perspective</td>
<td>Jun-16</td>
<td>Athens, Greece</td>
<td>Industry + academic</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>OECCPS</td>
<td>Optical Network Virtualization as a Enabler for 5G Network Slicing</td>
<td>Jul-16</td>
<td>Niigata, Japan</td>
<td>Industry + academic</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>ICTON 2016 5G Transport WS</td>
<td>Fixed mobile convergence: The COMBO vision</td>
<td>Jul-16</td>
<td>Trento, Italy</td>
<td>Industry + academic</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Mobile Cloud Workshop</td>
<td>Presentation at 4th MobileCloud Workshop</td>
<td>Jul-16</td>
<td>Milan, Italy</td>
<td>Academic</td>
<td>Not applicable</td>
<td></td>
</tr>
</tbody>
</table>
2.8 Educational activities

Among multiple educational activities implemented first of all by the academic Partners – in the form of lectures and courses, COMBO undertook three important endeavours for proper systematization and presentation of the FMC knowledge. Those are presented in details in the sub-chapters below.

2.8.1 Tutorial session at IEEE HPSR 2015 and publishing of recording and slides


The tutorial presentations are embedded into an overview of the past efforts, a summary of the state of the art, and a look-ahead for future convergent architectures and functionality. It is covering a motivation to fixed and mobile convergence, interconnected with an overview of the current state of the art. The convergence process is covered from both a structural convergence perspective, including infrastructure considerations, and a functional convergence point.

A recording was organized during this session and later on published on the COMBO website [3] in a structured manner, along with the slides presented – which is now publicly available. Below is the breakdown of tutorial sub-chapters in the same form as it is available on the website:

Figure 11 - Péter Olaszi (AITIA), Annie Gravey (IT-TB) and Björn Skubic (EAB) at IEEE HPSR 2015 tutorial session
1 Introduction [Slides]

1.1 Historical overview [Slides][Video]
1.2 The COMBO perspective [Slides][Video]

2 Functional convergence

2.0 Overview [Slides][Video]
2.1 Converged subscriber and session management [Slides][Video]
2.2 Advanced interface selection and route control
2.2.1 Unified Data Path Management [Slides][Video]
2.2.2 Decision Engine [Slides][Video]
2.2.3 Data Path Creation and Destruction [Slides][Video]
2.2.4 Path Coordination and Control - Based on RAN [Slides][Video]
2.2.5 Path Coordination and Control - Above the RAN [Slides][Video]
2.2.6 Path Coordination and Control - In the Application Layer [Slides][Video]

2.3 The Universal Access Gateway concept [Slides][Video]

3 Structural convergence

3.0 Overview [Slides][Video]
3.1 Motivation [Slides][Video]
3.2 Optimal BBU placement [Slides][Video]
3.3 Radio coordination [Slides][Video]
3.4 Access technology options [Slides][Video]
3.5 Backhaul [Slides][Video]
3.6 Fronthaul [Slides][Video]
3.7 Technology dimensioning and cost modelling [Slides][Video]
3.8 Preliminary results [Slides][Video]

4 Summary and conclusion [Slides][Video]
2.8.2 Editing of book for Springer "Optical Networks" series

This edited book has been submitted in June 2016 to publisher for final check and formatting and will be published (released to public) by the end of the year. The book chapters have been already finalized and collected. This book yields 14 chapters (three of which directly contributed from project partners) that investigate new enabling technologies for Fi-Wi (fiber-wireless) convergence. Fi-Wi technologies are comprehensively discussed at the three major network levels involved in the path towards convergence: system level, network architecture level, and network management level. The main topics are:

- System level: Radio over Fiber (digitalized vs. analogue, standardization, E-band and beyond) and 5G wireless technologies;
- Network architecture level: NGPON, WDM-PON, BBU Hotelling, Cloud Radio Access Networks (C-RANs), HetNets;
- Network management level: SDN for convergence, Next-generation Point-of-Presence, Wi-Fi LTE Handover, Cooperative MultiPoint.

This book is the first to comprehensively address all these topics from the point of view of Fi-Wi convergence and it aims at representing a reference manual in the coming years for researches, engineers, and practitioners working in the field.

The three editors of the book are Prof. Massimo Tornatore (POLIMI), Prof. G.K. Chang (Georgia Tech), and Prof. Georgios Ellinas (University of Cyprus). Contributors are from leading industrial and academic institutions: among the others ALU, AT&T, China Mobile, ZTE, NEC, Orange, etc.

The book features three contributions from project partners ALU7, POLIMI, ORANGE. ORANGE’s contribution provides a detailed introduction to the concept of NG-PoP, one of the key innovative proposals of COMBO. ALU’s and POLIMI’s contribution describe the current state of D-RoF standardizations and BBU hotelling architectures and will also promote the COMBO vision in the larger context of Fi-Wi convergence.

2.8.3 Open Online Education

The French government launched in 2014 a portal with an access to several Massive Open OnLine Courses (Mooc). Partner IT-TB is currently involved in the creation of a Mooc dedicated to 4G networks, which is given in French (“Comprendre la 4G, principes fondamentaux des réseaux mobiles des données”). COMBO produced a video to explain the objectives of fixed-mobile convergence and why convergence is a major issue for 5G networks. The first lesson was given on November 5th, 2015.

7 Exited project at Month 21
2.8.4 Webinars

COMBO has also completed and stored a series of webinars (3 webinars in total) which are available on the project website. Webinars were conducted on the following topics:

- Requirements for converged fixed and mobile networks;
- Framework reference for fixed and mobile;
- Roadmaps for independent fixed and mobile network evolution.

2.8.5 Inclusion of COMBO results into educational materials of academia partners

Apart from Open Online Education reported in 2.8.3, academic Partners from COMBO Consortium have included outcomes of the project into their lectures and courses. To name a few examples:

- At Lund University FMC is a natural topic included in the networking communication courses. In total there are about 300 students taking the introduction courses, and about 100 of them continue to the more advanced courses in the area.

- COMBO’s FMC concepts and its impact on the future network architectures became a part of various network related courses at Partner BME.

The motivation and need for Fixed Mobile Convergence, using the Use Cases defined by COMBO WP2 were used in a course related to “Convergent Networks and Services” for Electrical Engineer Master students, specialized in Infocommunication Systems.
The access/aggregation network infrastructure carrying both fixed and mobile traffic, and the respective requirements, technical solutions and architectures are a vital part of a course on “Optical Network Architectures” for Electrical Engineers specialized in Optical Telecommunications.

Finally, dimensioning and techno-economic investigation studies were subject of multiple Master thesis works of students in Informatics and Electrical Engineering.

- At POLIMI, FMC topics have been integrated in advanced courses as “Switching and Routing” and “Communication Network Design” of the Master program in Telecommunication Engineering and Internet Engineering. Concepts regarding both structural and functional convergence are now covered in these courses, and project assignments in these areas are assigned to students. In total there are about 120 students taking the two courses.

2.9 Collaboration with other initiatives

Collaboration with different initiatives can be tentatively divided into three groups:

- Exchange of information with external industrial players;
- Collaboration with FP7 projects and international/national initiatives/technology platforms;
- Collaboration with H2020 5G-PPP initiative projects;
- Joint events with other initiatives.

2.9.1 Industrial collaboration

Apart from active dissemination of the project results, COMBO was also several times approached by the external industrial players from all over the world and asked for additional specific information about project findings. Two example of such collaboration are online meetings with Telstra Corporation (Australia's largest telecommunications and media company) and with Corning Incorporated (Optical Communications division):

- Online meeting with Telstra Corporation (more specifically Telstra Mobile) took place on 24th of May 2016, and was attended by 9 people (6 from COMBO and 3 from Telstra Mobile). The presentations and discussion were mainly centered around low latency (cloud) applications and related COMBO work (e.g. impact of latency on Virtual Network Function distribution, Cloud-based service requirements in an FMC scenario, etc.).
- Discussion with Corning Optical Communications division took place on 16th of September 2016 and was attended by 5 people (4 from COMBO side and 2 from Corning side). The discussion was mainly related to the topic of structural convergence.
2.9.2 Collaboration with FP7 projects and international/national initiatives/technology platforms

Collaboration with the projects described below was organized by COMBO on several aspects, one of which is undoubtedly the uptake of other projects’ research results into COMBO own research. The planning of such uptake was setup in four areas, which are:

- Architectures;
- Ecosystems;
- Energy saving;
- Technology and physical layer (PHY).

The related projects were analysed for the most required inputs, which can be summarized as on following figure:

![Figure 14 – Principle of uptake of results from other initiatives by COMBO](image)

More particularly, actual collaboration was on-going with 14 projects in all 5 technological areas\(^{8}\), summarized in the following table:

---

\(^{8}\) See section 2.1 for the list and definitions of technological areas
For some of the FP7 projects listed above, efficient uptake of results by COMBO was enabled by the fact that one or several COMBO partners participated to these FP7 projects (as for OASE, ERMES, METIS, MCN, DISCUS to name a few). In addition, closer collaboration was built with some of the projects, among the ones which were active when COMBO started. As an illustration, several exchanges were organized with METIS project, so that COMBO could fully understand and address the requirements expected from 5G mobile networks and how they should be translated in an FMC context. This exchange with METIS continued up to early 2015, as METIS was close to its final results. This allowed in particular a fruitful interaction between the two projects on 5G transport requirements. As another example, several discussions and presentations were also organized between DISCUS and COMBO, as DISCUS architecture could have similarities with what COMBO proposes for structural convergence of transport resources. The final meeting between COMBO and DISCUS was organized during OFC in March 2015. The outcomes of this collaboration with DISCUS were summarized in an annex of deliverable D3.3 [4].

It also should be noted, that COMBO presented a joint paper [5] with DISCUS and iJOIN European Projects on 5G optical transport networks. A paper about 5G optical transport network was presented at ICTON 2015 including part of the results of COMBO, DISCUS and iJOIN regarding the promising network architectures with the potential to support the transport of 5G services.

### 2.9.3 Collaboration with H2020 5G-PPP initiative projects

After start of the 5G-PPP project back in July 2015 (or later) COMBO undertook thorough analysis of several 5G-PPP projects and short-listed the most appropriate ones in terms of technical area, which are most suitably positioned towards taking guidance fed by COMBO. This short list is as follows (in brackets is the technological field of the project, which is relevant to COMBO):

<table>
<thead>
<tr>
<th>FMC network architectures and NG-POP concept</th>
<th>Energy efficiency and green benefit of FMC</th>
<th>RAN design enabling FMC</th>
<th>Traffic engineering for FMC</th>
<th>Optical Access Network design for FMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCORDANCE</td>
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<td>X</td>
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<tr>
<td>C3PO</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>DISCUS</td>
<td>X</td>
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<tr>
<td>ECONET</td>
<td>X</td>
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<tr>
<td>ERMES</td>
<td></td>
<td></td>
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<td>X</td>
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<tr>
<td>ETICS</td>
<td>X</td>
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<tr>
<td>ETNO</td>
<td>X</td>
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<td></td>
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<tr>
<td>Greentouch</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>METIS</td>
<td>X</td>
<td></td>
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<tr>
<td>MCN</td>
<td>X</td>
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<tr>
<td>MUSE</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>OASE</td>
<td>X X</td>
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<tr>
<td>TREND</td>
<td>X</td>
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<tr>
<td>UNIFY</td>
<td>X</td>
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</tbody>
</table>

Table 7 – Uptake of other projects results into COMBO research
• 5G-Crosshaul [6] (former name XHAUL) – front-/back-/mid-haul architecture and design for 5G;
• 5Gex [7] - development of an open platform based on NFV/SDN for cross-domain orchestration;
• 5G-Xhaul [8] – dynamically reconfigurable converged optical and wireless network solution able to flexibly connect Small Cells to the core network;
• CHARISMA [9] - cloud infrastructure platform for secured, low-latency converged wireless/wireline advanced 5G networking.

In the early stages of these projects (i.e. end of 2015) COMBO has proactively approached them in order to arrange presentations and agree on collaboration fields more precisely. On a later stages (starting from 2016), several joint initiatives were performed together with these projects, such as joint workshops or joint papers. For example, two workshops with mentioned projects were held on EuCNC 2016:

• Workshop on "Towards Converged X-Haul for 5G Networks – A joint workshop of the iCirrus, 5G-XHaul and 5G-Crosshaul projects", where presentation „COMBO architectures for fixed and mobile network integration in 5G" was given;
• Workshop on Next generation fronthaul/backhaul integrated transport networks, organized by 5G-Crosshaul project, where presentation “Backhaul/Fronthaul for future 5G transport: COMBO perspective” was given.

Moreover, the joint paper "Network Requirements for Latency-Critical Services in a Full Cloud Deployment" authored by Stefan Höst, William Tärneberg, Per Ödling, Maria Kihl, Marco Saviy and Massimo Tornatore was created in collaboration with 5G-Crosshaul project.

It should be also explicitly noted, that COMBO is also officially one of the “feeding” projects of 5G-PPP [10]. Furthermore, COMBO is listed in an NGMN deliverable as one of the FP7 projects “preparing the evolution to 5G and having connections with RAN evolutions through interfaces definitions, virtualization aspects or new architectures” [11].

2.9.4 Joint events with other initiatives

In addition to joint events mentioned in previous section, several workshops and panels occurred, some of which were organized by COMBO, occasionally in collaboration with other initiatives:


   *Led by COMBO, this special session included 5 presentations on different topics, including a presentation from CROWD project.*

This workshop was organized by COMBO. Several EU projects representatives (ERMES, DISCUS, IDEALIST, CONTENT) were invited.


   This workshop was organized by COMBO and the program included presentations by DISCUS, SODALES, CONTENT, Mobile Cloud Networking and METIS EU projects representatives.


   This 2-parts workshop gathered a number of speakers (more than 10) from operators, vendors and academia, where COMBO (via DTAG) has contributed with the operator view on node consolidation (whereas DISCUS project contributed with their view on network architecture).

5. Workshop at the 12th Conference of Telecommunication, Media and Internet Techno-Economics (CTTE) [16], Munich, Germany, 9-10 of November 2015.

   This workshop was organized by COMBO project, included a total of 7 papers, and allowed exchange of information between 5 projects (COMBO, ICIRRUS, 5G-XHAUL, CHARISMA, 5G-CROSSHAUL).


   This workshop brought together views from ongoing research projects (STRAUSS, IDEALIST, DISCUS, COMBO) as well as Industrial actors (both network operators and vendors) on hot topics and current trends in SDN and NFV. The talk on behalf of COMBO (by ADVA) entitled “NFV-based Universal Access for converged fixed and mobile broadband access/aggregation networks” was given.

2.10 Other dissemination activities

2.10.1 Smaller scale demonstrations

AITIA, as an industrial partner of the BME Department of Telecommunications and Media Informatics, contributes to the university education activities. The Amari LTE system obtained for the COMBO demonstration is offered by AITIA for demonstration and educational purposes at the university department.

The COMBO 3D Handover demonstration has been presented in cooperation with AITIA at the HPSR 2015 conference, to Magyar Telekom and Ericsson Hungary, as well as to students of BME. It is presented at the Hungarian “Night of Researchers” on September 30, 2016 (and will be part of this public educational event in the
coming years). The development and demonstration of 3D Handover was part of COMBO deliverables D3.2 [18], D3.5 [19] and D6.3 [20].

2.10.2 Press coverage

2.10.2.1 Press releases by Consortium partners

Several press releases were issued by Consortium partners especially after completion of demonstration event and highlighted COMBO role in shaping future fixed and mobile networks. Below are several screenshots – from press releases of Partners FON, ADVA and TELNET:

![Figure 15 – FON press release](image)

![Figure 16 – ADVA press release](image)
2.10.2.2 Press coverage

A very extensive coverage in the Turkish press was organized by Partner ARGELA prior to the project’s plenary meeting in Istanbul in September 2015. Below is the list of several links with the press releases and screenshot from one of the websites:

- http://shiftdelete.net/teknoloji-devleri-5g-icin-istanbulda-62693
2.11 Collaborative publications

This chapter explicitly details 27 technical papers (conferences and journals) that resulted from joint work – either between Consortium Partners – or between COMBO Partner(s) and other industrial or academic organizations. Note that all papers are already mentioned in sections 2.2 - 2.5, and in the following table we only highlight collaborative ones. Columns with type of audience and URL to publisher are suppressed for better readability of table.
<table>
<thead>
<tr>
<th>№</th>
<th>Name of conference or journal</th>
<th>Author(s)</th>
<th>Title</th>
<th>Date/Period</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OFC/NFOEC 2013</td>
<td>D. Breuer, E. Weis, S. Gosselin, T. Mamouni, J. Torrijos</td>
<td>Unified Access and Aggregation Network Allowing Fixed and Mobile Networks to Converge</td>
<td>Mar-13</td>
<td>Anaheim, USA</td>
</tr>
<tr>
<td>4</td>
<td>FuNeMS 2013</td>
<td>Philippe CHANCLOU, Anna PIZZINAT, Fabien LE CLECH, To-Linh REEDEKER, Yannick LAGADEC, Fabienne SALIOU, Bertrand LE GUYADER, Laurent GUILLO, Qian DENIEL, Stéphane GOSSELIN, Sy Dat LE, Thierno DIALLO, Romain BRENOT, Francois LELARGE, Lucia MARAZZI, Paola PAROLARI, Mario MARTINELLI, Sean O’DULL, Simon Arega GEBREWOLD, David HILLERKUSS, Juerg LEUTHOLD, Giancarlo GAVIOLI, Paola GALLI</td>
<td>Optical fiber solution for mobile fronthaul to achieve Cloud Radio Access Network</td>
<td>Jul-13</td>
<td>Lisbon, Portugal</td>
</tr>
<tr>
<td>6</td>
<td>ISCC2014</td>
<td>M.Feknous, T.Houdoin, B.Le Guyader, J.De biasio, A.Gravey, Jose Torrijos</td>
<td>Internet Traffic Analysis: A Case Study From Two Major European Operators</td>
<td>Jun-14</td>
<td>Madeira, Portugal</td>
</tr>
<tr>
<td>7</td>
<td>Photonics Journal, MDPI</td>
<td>Paola Garfias, Manlet De Andrade, Massimo Tornatore, Anna Buttaboni, Sebastià Sallent, Lluís Gutiérrez</td>
<td>Energy-saving mechanism in WDM/TDM-PON based on upstream network traffic</td>
<td>Aug-14</td>
<td>Not applicable</td>
</tr>
<tr>
<td>9</td>
<td>Advances in Computer Science: an International</td>
<td>Moufida Feknous, Bertrand Le Guyader, Pal Varga, Annie Gravey, Stéphane Gosselin, Jose Alfonso Torrijos Gijon</td>
<td>Multi-Criteria Comparison Between Legacy and Next Generation Point of Presence Broadband Network Architectures</td>
<td>May-15</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Journal</td>
<td>Authors</td>
<td>Title</td>
<td>Conference/Date</td>
<td>Location</td>
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<tr>
<td>10 IEEE CLOUDNET conference</td>
<td>Marilet De Andrade, Massimo Tornatore, Achille Pattavina, Ali Hamidian, Klaus Grobe</td>
<td>Cost Models for Baseband Unit (BBU) Hotelling: from Local to Cloud</td>
<td>May-15</td>
<td>Niagara Falls, Canada</td>
<td></td>
</tr>
<tr>
<td>11 EuCNC 2015</td>
<td>Tahar Mamouni, Jose A. Torrijos Gijón, Péter Olaszi, Xavier Lagrange</td>
<td>Universal AAA for hybrid accesses</td>
<td>Jun-15</td>
<td>Paris, France</td>
<td></td>
</tr>
<tr>
<td>17 ECOC 2015</td>
<td>Nicola Carapellese, Massimo Tornatore, Achille Pattavina, Stephane Gosselin</td>
<td>BBU Placement over a WDM Aggregation Network Considering OTN and Overlay Fronthaul Transport</td>
<td>Sep-15</td>
<td>Valencia, Spain</td>
<td></td>
</tr>
<tr>
<td>Communications and Networking</td>
<td>Younes Khadraoui, Xavier Lagrange, Annie Gravey</td>
<td>Performance analysis of LTE-WiFi very tight coupling</td>
<td>Jan-16</td>
<td>Las Vegas, USA</td>
<td></td>
</tr>
<tr>
<td>#</td>
<td>Conference/Academic Journal</td>
<td>Title/Abstract of Paper/Symposium</td>
<td>Publication/Presentation Date</td>
<td>City/Country</td>
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</tr>
<tr>
<td>22</td>
<td>IEEE/OSA Journal of Lightwave Technology</td>
<td>Francesco Musumeci, Camilla Bellanzon, Nicola Carapellese, Massimo Tornatore, Achille Pattavina and Stephane Gosselin</td>
<td>Optimal BBU Placement for 5G C-RAN Deployment Over WDM Aggregation Networks</td>
<td>Mar-16</td>
<td>N#A</td>
</tr>
<tr>
<td>23</td>
<td>JOURNAL OF LIGHTWAVE TECHNOLOGY</td>
<td>Peter Ohlen, Bjorn Skubic, Ahmad Rostami, Matteo Fiorani, Paolo Monti, Zere Ghebretensae, Jonas Martensson, Kun Wang, and Lena Wosinska</td>
<td>Data Plane and Control Architectures for 5G Transport Networks</td>
<td>Mar-16</td>
<td>N#A</td>
</tr>
<tr>
<td>25</td>
<td>ICTON 2016</td>
<td>Marco Savi, Ali Hmaity, Giacomo Verticale, Stefan Höst, Massimo Tornatore</td>
<td>To Distribute or Not to Distribute? Impact of Latency on Virtual Network Function Distribution at the Edge of FMC Networks</td>
<td>Jul-16</td>
<td>Trento, Italy</td>
</tr>
<tr>
<td>26</td>
<td>SoftCom2016</td>
<td>Stefan Höst, William Tärneberg, Per Ödling, Maria Kihl, Marco Savi, Massimo Tornatore</td>
<td>Network Requirements for Latency-Critical Services in a Full Cloud Deployment</td>
<td>Sep-16</td>
<td>Split, Croatia</td>
</tr>
<tr>
<td>27</td>
<td>SoftCom 2016</td>
<td>Stefan Höst, William Tärneberg, Per Ödling, Maria Kihl, Marco Savy, Massimo Tornatore</td>
<td>Network Requirements for Latency-Critical Services in a Full Cloud Deployment</td>
<td>Sep-16</td>
<td>Split, Croatia</td>
</tr>
</tbody>
</table>
3 Conclusion

A number of activities were performed by COMBO during its lifetime in order to spread the information to the community and in order to influence state of the art developments in the relevant fields.

The Consortium has experienced high demand towards the integrated view on FMC aspects from the number of stakeholders. The number of invited papers and talks (15 conference papers, 6 journal papers, 3 keynotes, 25 workshop presentations including FSAN workshop), tens of people attending demo day and collaboration with industry from worldwide proves that. We consider that COMBO was in position to adequately address this demand – this not only via spreading scientific knowledge via traditional measures (e.g. conference papers), but also via demonstration (including continuously available video material), via number of educational materials and comprehensive FMC tutorial.

While COMBO is ending, a number of different other initiatives, directly or indirectly influenced by COMBO is continuing.
4 References

[1] COMBO deliverable D7.1 - Project presentation, communication plan and dissemination plan


[10] https://5g-ppp.eu/projects/


