D7.2 INTERMEDIATE REPORT ON STANDARDIZATION AND DISSEMINATION ACTIVITIES

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Project coordinator name, title and organisation: Jean-Charles Point, JCP-Connect

Tel: + 33 2 23 27 12 46

E-mail: pointjc@jcp-consult.com

Project website address: www.ict-combo.eu

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Executive Summary of the Deliverable

During first two periods the COMBO project has generated a number of knowledge, which was further disseminated via number of measures. The project results have reached wider community via different channels: printed materials, press releases, events, publications, standardization organizations and educational materials.

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

- 52 accepted papers at conferences;
- 10 journal papers, including 3 invited ones;
- (19 papers among two above are done in collaboration – either internal (i.e. several Partners of the Consortium), or external);
- 11 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 and conferences;
- Organized 4 workshops and gave 12 presentations at workshops/panels;
- 3 Broadband Forum Working Texts;
- 1 White paper intended to ETSI.

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

In the standardization field the Universal Access Gateway White Paper issued by the project and intended to ETSI, is currently fulfilling the role of preparing the framework for the future standardization of convergent nodes in the networks.

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

Full Name – E-mail	Company – Country Code
Roman Kaurson – roman.kaurson@jcp-connect.com	JCP-Connect - FR
Serban Purge - serban.purge@orange.com	Orange - FR
Massimo Tornatore - massimo.tornatore@polimi.it	POLIMI - IT
Ali Hamidian - ali.hamidian@ericsson.com	EAB - SE
Dirk Breuer - D.Breuer@telekom.de	DTAG - DE
Stephane Gosselin - stephane.gosselin@orange.com	Orange - FR
Xavier Lagrange - xavier.lagrange@telecom-bretagne.eu	IT-TB - FR
Stefan Höst - stefan.host@eit.lth.se	ULUND - SE
Attila Mitcsenkov - mitcsenkov@tmit.bme.hu	BME - HU
Jose Alfonso Torrijos Gijon - jose.torrijosgijon@telefonica.com	TID-ES

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Glossary

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

1 Introduction

Present document describes the dissemination and standardization activities performed by the COMBO project from its beginning (January 2013) until the end of second period (September 2015)[1].

1.1 Dissemination

The dissemination activities in the project were conducted according to general principles, described in the deliverable D7.1 [1]. Thus, present document describes broad set of the activities which 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 5GPP projects.

In the next chapters all dissemination activities are categorized and reported more precisely.

1.2 Standardization

As far as the standardization activities of the project are concerned, this document presents (i) the methodology implemented for pushing project's results into standards and (ii) the main results of the standardization activities for the aforementioned period.

The innovative technological perimeters of the project and their relation to standard organizations (SDOs) are also presented in the standardization part of the document.

The standardization part covers also the pre standardization activities, i.e. those activities having the main goal of creating industries or communities momentums for setting the floor for the standardization of the COMBO concepts.

[1] Dissemination activity generally belongs into considered period if the submission of paper, workshop etc. was done within considered period.

2 Project presentation material

2.1 Website

The website of the COMBO project (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.

Figure 1 – COMBO website screenshot

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

- HOME (return to the home page);
- ABOUT (project description);
- DELIVERABLES (deliverables of the project);
- PROJECTS (projects having collaboration with COMBO);
- DISSEMINATION (project scientific and technical output);
- FMC TUTORIAL 2015 (comprehensive collection of videos and slides related to FMC prepared and recorded on one of the events).

2.2 Printed material

2.2.1 Poster

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

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

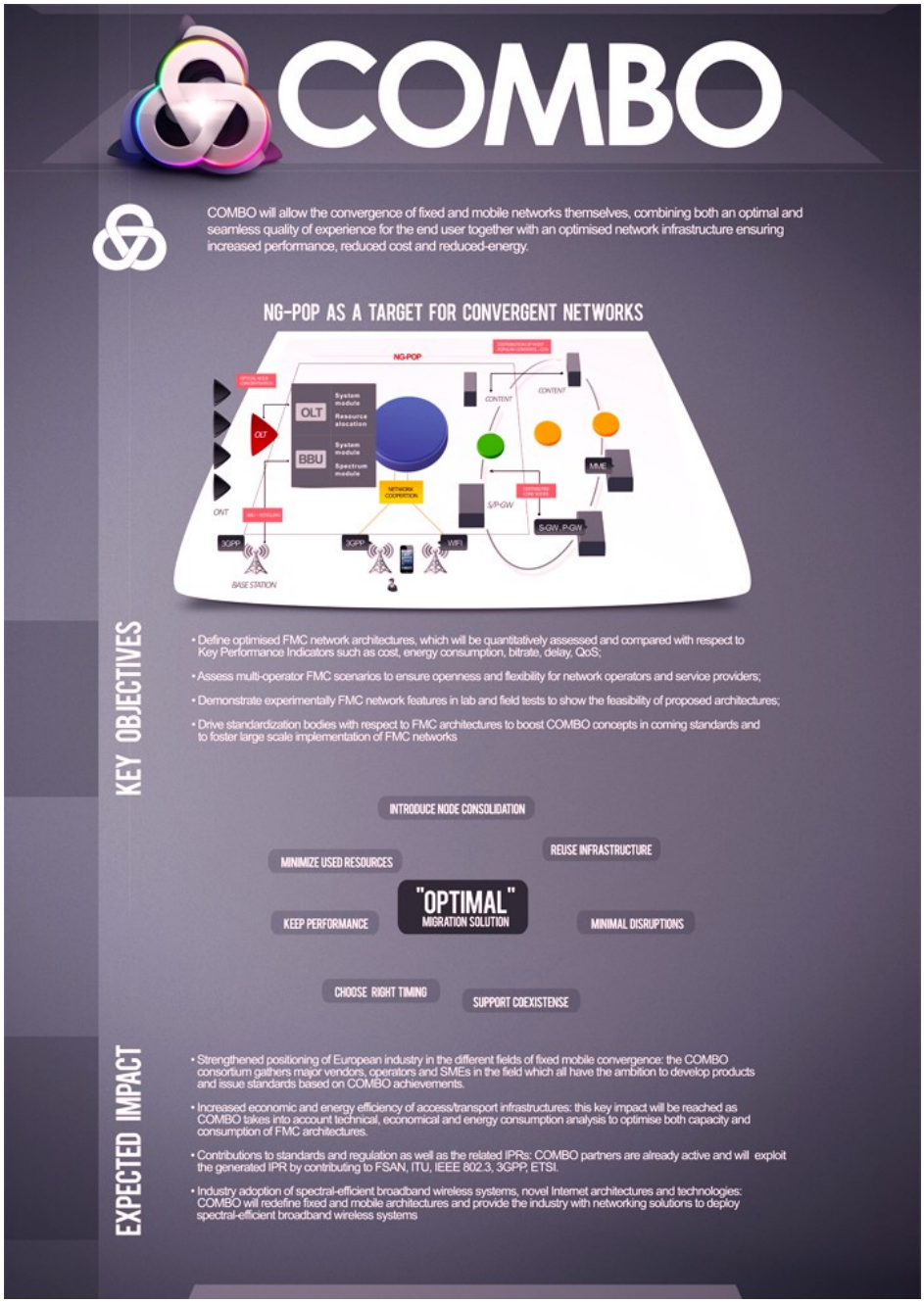


Figure 2 – Initial version of COMBO poster

Next revision of poster started in spring 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. 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:

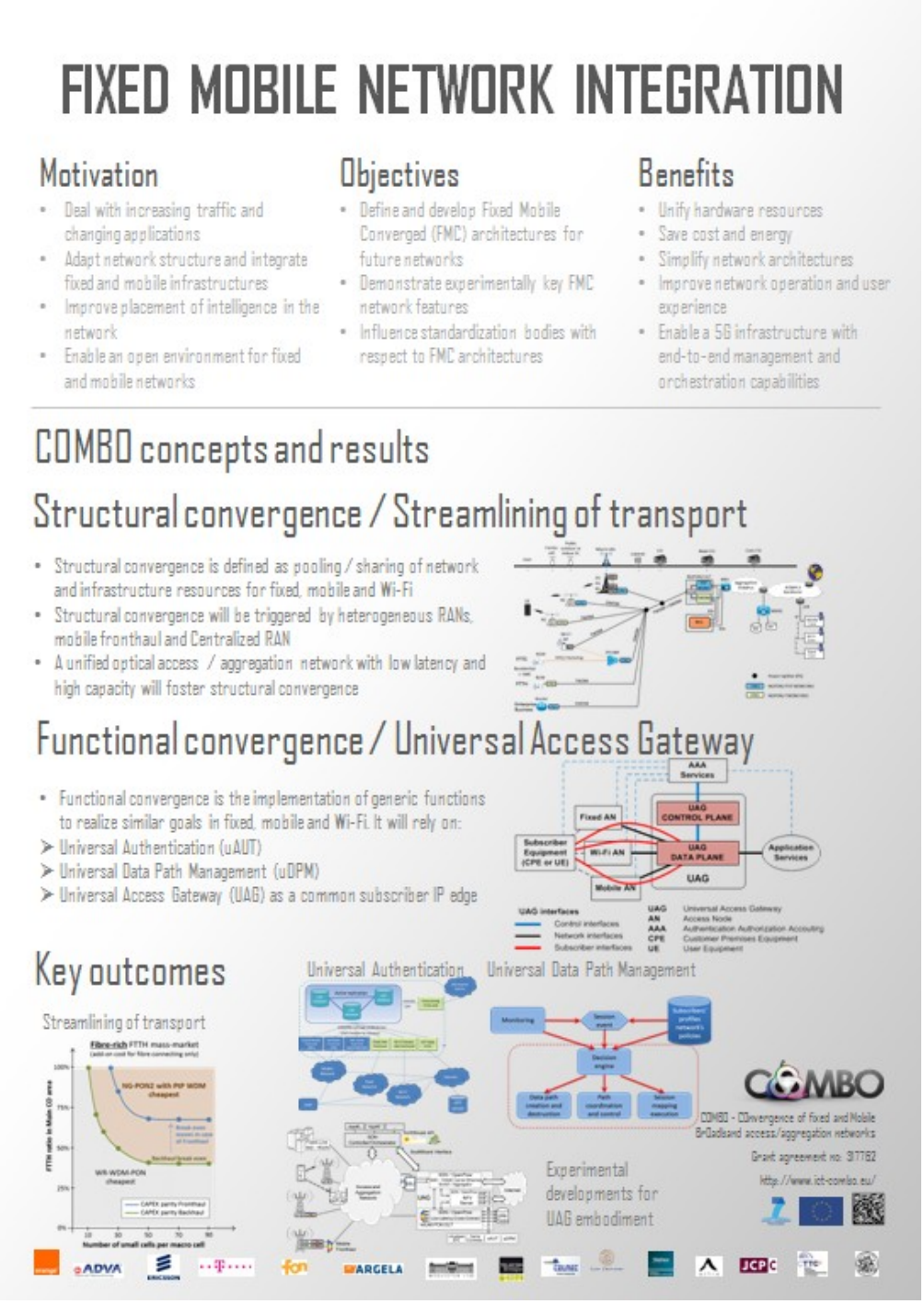
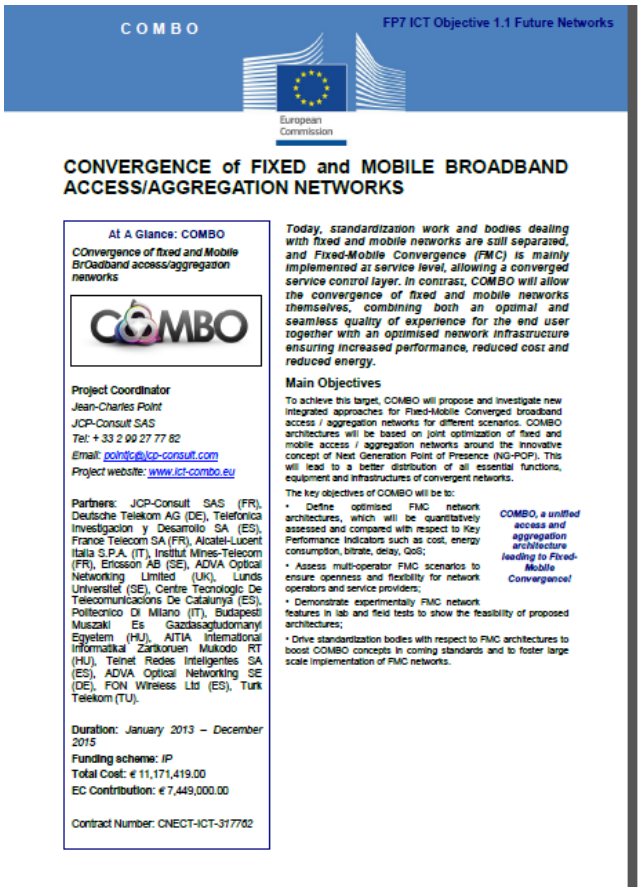


Figure 3 – Revised version of COMBO poster

2.2.2 Leaflet

Similarly to poster, two round of creation of leaflets happened in COMBO up to present time (September 2015).

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



COMBO

FP7 ICT Objective 1.1 Future Networks

European Commission

CONVERGENCE of FIXED and MOBILE BROADBAND ACCESS/AGGREGATION NETWORKS

At A Glance: COMBO

COnvergence of fixed and Mobile BrOadband access/aggregation networks

Project Coordinator

Jean-Charles Point

JCP-Consult SAS

Tel: + 33 2 99 27 77 82

Email: point@jcp-consult.com

Project website: www.ict-combo.eu

Partners: JCP-Consult SAS (FR), Deutsche Telekom AG (DE), Telefonica Investigacion y Desarrollo SA (ES), France Telecom SA (FR), Alcatel-Lucent Italia S.P.A. (IT), Institut Mines-Telecom (FR), Ericsson AB (SE), ADVA Optical Networking Limited (UK), Lunds Universitet (SE), Centre Tecnologic De Telecomunicacions De Catalunya (ES), Politecnico Di Milano (IT), Budapesti Muszaki Es Gazdasagtudomanyi Egyetem (HU), AITIA International Informatikai Zartkoruen Mukodo RT (HU), Telnet Redes Inteligentes SA (ES), ADVA Optical Networking SE (DE), FON Wireless Ltd (ES), Turk Telekom (TU).

Duration: *January 2013 – December 2015*

Funding scheme: *IP*

Total Cost: € 11,171,419.00

EC Contribution: € 7,449,000.00

Contract Number: CNECT-ICT-317762

Today, standardization work and bodies dealing with fixed and mobile networks are still separated, and Fixed-Mobile Convergence (FMC) is mainly implemented at service level, allowing a converged service control layer. In contrast, COMBO will allow the convergence of fixed and mobile networks themselves, combining both an optimal and seamless quality of experience for the end user together with an optimised network infrastructure ensuring increased performance, reduced cost and reduced energy.

Main Objectives

To achieve this target, COMBO will propose and investigate new integrated approaches for Fixed-Mobile Converged broadband access / aggregation networks for different scenarios. COMBO architectures will be based on joint optimization of fixed and mobile access / aggregation networks around the innovative concept of Next Generation Point of Presence (NG-POP). This will lead to a better distribution of all essential functions, equipment and infrastructures of convergent networks.

The key objectives of COMBO will be to:

- Define optimised FMC network architectures, which will be quantitatively assessed and compared with respect to Key Performance Indicators such as cost, energy consumption, bitrate, delay, QoS;
- Assess multi-operator FMC scenarios to ensure openness and flexibility for network operators and service providers;
- Demonstrate experimentally FMC network features in lab and field tests to show the feasibility of proposed architectures;
- Drive standardization bodies with respect to FMC architectures to boost COMBO concepts in coming standards and to foster large scale implementation of FMC networks.

COMBO, a unified access and aggregation architecture leading to Fixed-Mobile Convergence!

Technical Approach

Besides management, the project is divided into the following workpackages:

WP2 Framework definition, Architecture and Evolution: provides the general framework and use cases for fixed and mobile networks and assess current evolution trends and traffic demands. Identifies the requirements and Key Performance Indicators (KPI) that will have to be considered during the FMC network architectures design.

- Deal with rapidly increasing traffic and changing applications
- Adapt Network structure according to the different requirements of fixed and mobile networks
- Identify where to place intelligence in the network
- Enable multi-operator/multi-vendor environment
- Seamless performance monitoring and

NGPOP as a target for convergent networks

Distribution of most popular contents, CDN

NG-POP

Content

Optical node concentration

OLT

ONT

Content

MME

S/P-GW

Distributed Core Nodes

S-GW, P-GW

DSU handling

Base station

WP3 Fixed Mobile Convergent architectures: proposes, defines and assesses candidate architectures for future FMC networks. It compares in detail the candidate FMC architectures

WP4 Traffic and performance management defines the measureable QoS parameters that reflect the FMC network optimization criteria. It also develops a system for optimised network management based on performance monitoring and performance management tools.

WP5 Techno-economic Assessment quantitatively assesses proposed FMC network architectures based on cost and energy consumption calculations. It also assesses the impact of network convergence on business ecosystems.

WP6 Functional Development & Experimental Research Activities demonstrates experimentally varying levels of network convergence identified within the project.

WP7 Dissemination and Standardization coordinates and performs project results dissemination and exploitation, with a particular focus on standardization and discussion fora.

Key Issues

- Save costs including CAPEX and OPEX management in shared networks
- Reduce Energy consumption

Expected Impact

- Strengthened positioning of European industry in the different fields of fixed mobile convergence: the COMBO consortium gathers major vendors, operators and SMEs in the field which all have the ambition to develop products and issue standards based on COMBO achievements.
- Increased economic and energy efficiency of access/transport infrastructures: this key impact will be reached as COMBO takes into account technical, economical and energy consumption analysis to optimise both capacity and consumption of FMC architectures.
- Contributions to standards and regulation as well as the related IPRs: COMBO partners are already active and will exploit the generated IPR by contributing to FSAN, ITU, IEEE 802.3, 3GPP, ETSI.
- Industry adoption of spectral-efficient broadband wireless systems, novel internet architectures and technologies: COMBO will redefine fixed and mobile architectures and provide the industry with networking solutions to deploy spectral-efficient broadband wireless systems.

COMBO

February 2013

Figure 4 – Initial version of the COMBO project leaflet

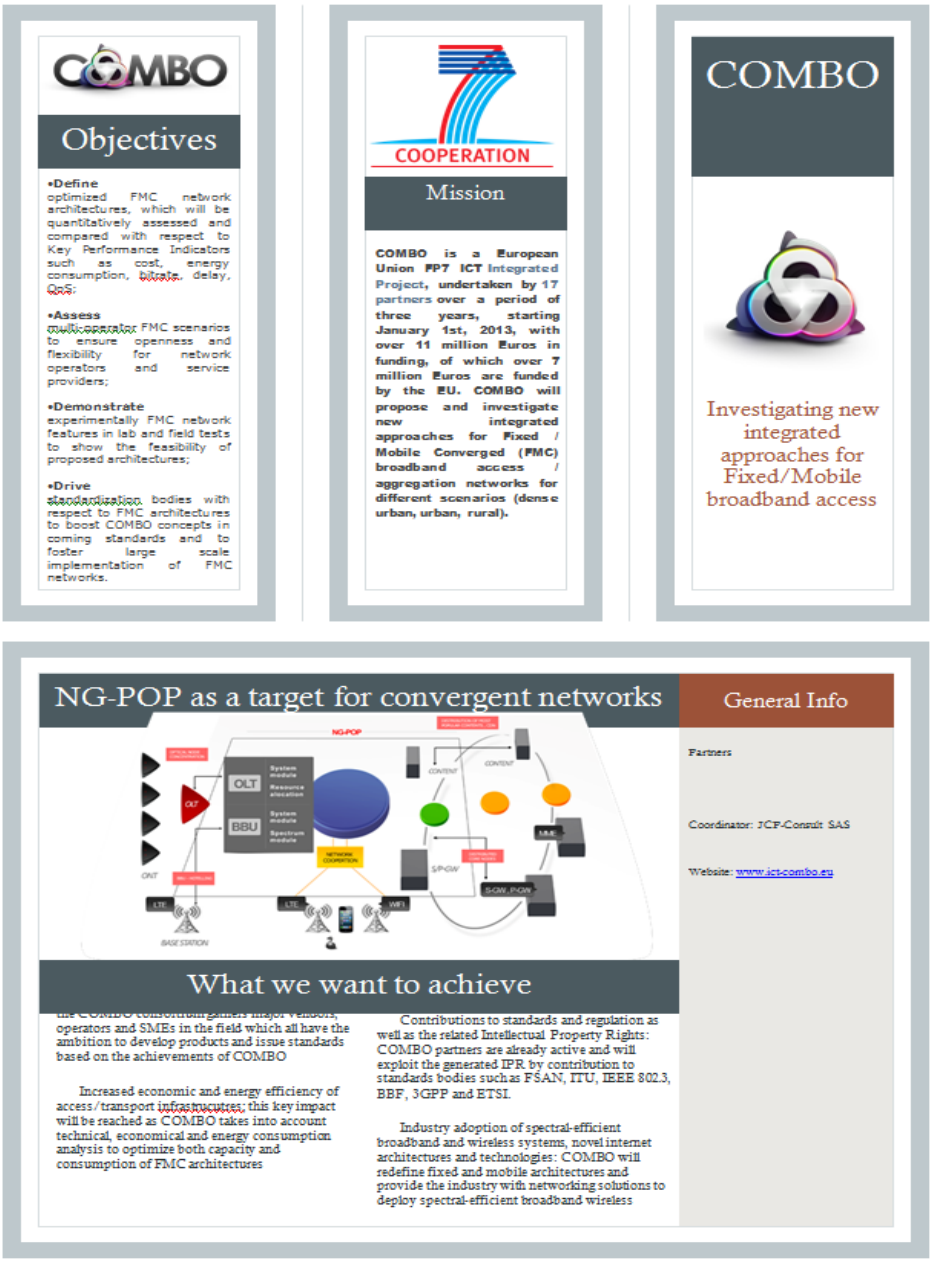


Figure 5 – initial three-fold leaflet of COMBO project

Similarly to poster, a clean-slate approach to leaflet design was undertaken in spring 2015. New version of leaflet was issued in parallel with the poster and has similar style and information on it, which can be seen below.

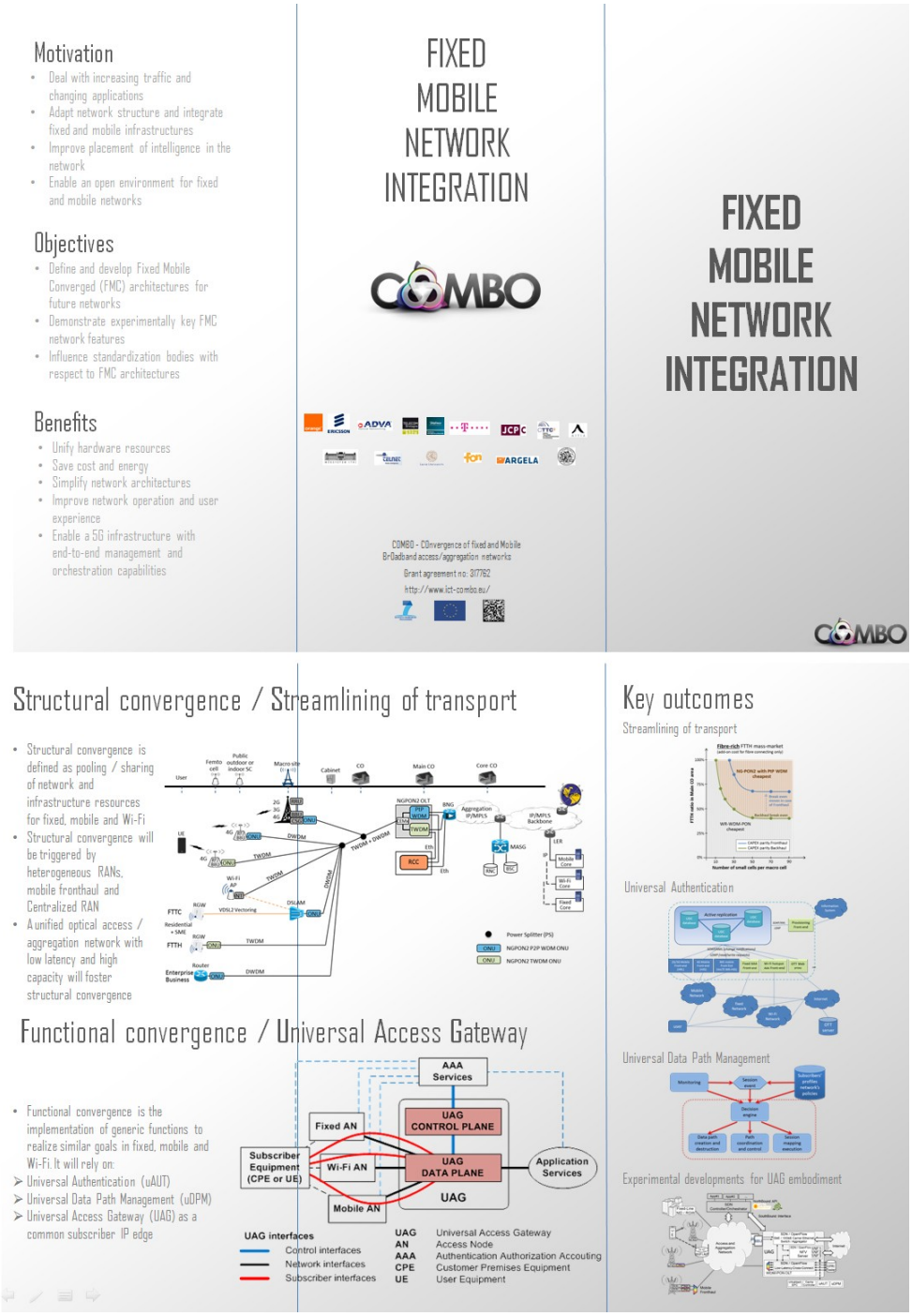


Figure 6 – revised version of three-fold leaflet of COMBO project

3 Dissemination activities performed during considered period

3.1 Introduction

The dissemination activities in COMBO are divided into several groups for ease of categorization and navigation – for both consortium and for 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 international 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. Those activities are described separately in the following chapters.

In addition to categorization of type 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

Following chapters also briefly describe areas, where COMBO contribution is most significant.

3.2 Peer-reviewed technical papers in international conferences

This group is the largest one with total of 52 accepted papers, which were presented in 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 (19 papers), followed by "E - Optical Access Network design for FMC" and "D - Traffic engineering for FMC" (13 and 10 papers respectively). 8 publications covered "C - RAN design enabling FMC" and 5 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 result of joint work of several organizations – either belonging to COMBO consortium, or even outside. Current chapter, however, describes all peer-reviewed technical papers in total, whereas selection of collaborative publications is given explicitly in chapter 3.10.

The table below presents all mentioned technical publications in chronological order.

№	Name of event	Author(s)	Title	Period	Place	Type of audience	URL
1	OFC/NFOEC 2013	D. Breuer, E. Weis, S. Gosselin, T. Mamouni, J. Torrijos	Unified Access and Aggregation Network Allowing Fixed and Mobile Networks to Converge	Mar-13	Anaheim, USA	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6533005
2	ONDM 2013	N. Carapellese, M. Tornatore, A. Pattavina	Placement of Base-Band Units (BBUs) over Fixed/Mobile Converged Multi-Stage WDM-PONs	Apr-13	Brest, France	Industry + academic	http://goo.gl/4Z92rW
3	ICC2013	Julio Araujo, Frederic Giroire, Yaning Liu	Energy Efficient Content Distribution	Jun-13	Budapest, Hungary	Industry + academic	http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=6655228&queryText%3DEnergy+Efficient+Content+Distribution
4	ICC2013	Yaning Liu, Joost Geurts	Dynamic Adaptive Streaming over CCN: A Caching and Overhead Analysis	Jun-13	Budapest, Hungary	Industry + academic	http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=6655116&queryText%3DDynamic+Adaptive+Streaming+over+CCN%3A+A+Caching+and+Overhead+Analysis
5	FuNeMS 2013	S. Gosselin, T. Mamouni, P. Bertin, J. Torrijos, D. Breuer, E. Weis, J.-C. Point	Converged fixed and mobile broadband networks based on Next Generation Point of Presence	Jul-13	Lisbon, Portugal	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6633581
6	FuNeMS 2013	Philippe CHANCLOU at al.[2]	Optical fiber solution for mobile fronthaul to achieve Cloud Radio Access Network	Jul-13	Lisbon, Portugal	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6633565
7	FuNeMS 2013	A. Pattavina	Towards a Convergent Fixed-mobile Access-aggregation Infrastructure for Energy-efficient Broadband Networking: the COMBO project	Jul-13	Lisbon, Portugal	Industry + academic	http://cordis.europa.eu/fp7/ict/future-networks/documents/call8-projects/combo.pdf

[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 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

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	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	http://www.cttc.es/publication/dynamic-provisioning-via-a-stateful-pce-with-instantiation-capabilities-in-gmpls-controlled-flexi-grid-dwdm-networks/
10	ECOC 2013	K. Grobe	Access Networks Based on Tunable Transmitters (Invited)	Sep-13	London, UK	Industry + academic	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	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. Mitcsenkov, G. Paksy, B. Molnar, R. Ando	Energy-Availability-QoS Trade-off for Future Converged Fixed-Mobile Networks	Dec-13	Budapest, Hungary	Academic	http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6719305
13	CCSCI 2014	M. Feknous, B. Le Guyader, and A. Gravey	Revisiting Access and Aggregation Network Architecture	Jan-14	Toronto, Canada	Industry + academic	https://portail.telecom-bretagne.eu/publi/public/fic_download.jsp?id=21164
14	OFC/ NFOEC 2014	Annie Gravey, Philippe Gravey, Michel Morvan, Bogdan Uscumlic, Lida Sadeghioon	QoS of Optical Packet Metro networks	Mar-14	San Francisco California, USA	Industry + academic	https://portail.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	http://goo.gl/lApNK4

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
17	WCNC 2014	X. Lagrange	Very Tight Coupling between LTE and Wi-Fi for Advanced Offloading Procedures	Apr-14	Istanbul, Turkey	Industry + academic	https://portail.telecom-bretagne.eu/publi/public/fic_download.jsp?id=14091
18	EW2014	S. Gosselin et al.[3]	Fixed and Mobile Convergence: Needs and Solutions	May-14	Barcelona Spain	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6843174
19	ONDM 2014	A. Mitcsenkov, T. Cinkler	Topology-dependent selective and partial protection of optical access networks	May-14	Stock-holm, Sweden	Industry + academic	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6855769
20	15. ITG-Fachtagung "Photonische Netze"	Carsten Behrens, Ralf Hülsermann, Dirk Breuer	FMC traffic model for aggregation networks	May-14	Leipzig, Germany	Industry + academic	http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=6839967&queryText%3DFMC+traffic+model+for+aggregation+networks
21	EW2014	Nicola Baldo, Ricardo Martinez, Paolo Dini, Ricard Vilalta, Marco Miozzo, Ramon Casellas, Raul Muñoz	A Testbed for Fixed Mobile Convergence Experimentation: ADRENALINE-LENA Integration	May-14	Barcelona Spain	Academic	http://www.cttc.es/publication/a-testbed-for-fixed-mobile-convergence-experimentation-adrenaline-lena-integration/
22	EW2014	Y. Khadraoui, X. Lagrange, A. Gravey	A Survey of Available Features for Mobile Traffic Offload	May-14	Barcelona Spain	Academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6843152
23	EW2014	Pál Varga, Péter Olaszi	Traffic modeling methods to support performance management in FMC scenarios	May-14	Barcelona Spain	Academic	

[3] Full list of authors is hided for optimum space usage. Full list of authors for this publication is S. Gosselin, J. De Biasio, M. Feknous, T. Mamouni, J. Torrijos, L. Cucala, D. Breuer, E. Weis, F. Geilhardt, D. v. Hugo, E. Bogenfeld, A. Hamidian, N. Fonseca, Y. Liu, S. Kuehrer, A. Gravey, A. Mitcsenkov, J.V. Galán, E. Masgrau, L. Gómez, L. Alonso, S. Höst, A. Magee

24	ONDM 2014	Ahmed Triki, Ramon Aparicio-Pardo, Paulette Gavignet, Esther Le Rouzic, B. Arzur, A. Gravey	Is It Worth Adapting Sub-Wavelength Switching Control Plane to Traffic Variations	May-14	Stock-holm, Sweden	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6855782
25	ICC2014	Giacomo Verticale, Massimo Tornatore	Using Replicated Video Servers for VoD Traffic Offloading in Integrated Metro/Access Networks	Jun-14	Sydney, Australia	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6883853
26	ISCC2014	M.Feknous, T.Houdoin, B.Le Guyader, J.De biasio, A.Gravey, Jose Torrijos	Internet Traffic Analysis: A Case Study From Two Major European Operators	Jun-14	Madeira, Portugal	Academic	http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6912519
27	EuCNC 2014	Y. Khadraoui, X. Lagrange	Virtual residential gateways: Architecture and performance	Jun-14	Bologna, Italy	Industry + academic	https://portail.telecom-bretagne.eu/publi/htdocs/publi.jsp?id_publication=14440
28	ICTON 2014	József Czékus, Péter Megyesi, Attila Mitcsenkov, Dániel Mazroa	Hardware Cost and Capacity Analysis of Future TDM- and WDM-PON Access Networks	Jul-14	Graz, Austria	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6876474
29	Networks 2014	Anna Buttaboni, Marilet De Andrade, Massimo Tornatore	Dynamic Bandwidth and Wavelength Allocation with Coexistence of Transmission Technologies in TWDM PONs	Sep-14	Madeira, Portugal	Industry+ Academic	http://networks2014.av.it.pt/
30	ECOC 2014	M. Tornatore	An Energy Consumption Comparison of Different Mobile Backhaul and Fronthaul Optical Access Architectures	Sep-14	Cannes, France	Industry+ Academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6964023
31	SOFTCOM 2014	J. Andersson, S. Höst, D. Cederholm, M. Kihl	On the Relation Between Impulse Noise and IP	Sep-14	Split, Croatia	Academic	http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=4648156&fileOId=4648206
32	Eunice 2014	Souheir Eido, Annie Gravey	How much LTE traffic can be offloaded?	Sep-14	Rennes, France	Academic	https://www.telecom-bretagne.eu/publications/publication.php?idpublication=14489

33	Eunice 2014	MITHARWAL Pratibha, LOHR Christophe, GRAVEY Annie	Survey on Network Interface Selection in Multihomed Mobile Networks	Sep-14	Rennes, France	Academic	https://www.telecom-bretagne.eu/publications/publication.php?idpublication=14488
34	LatinCom 2014	Giacomo Verticale, Massimo Tornatore	Energy-Efficient VoD Content Delivery and Replication in Integrated Metro/Access Networks	Nov-14	Cartage-na, Colombia	Industry + academic	http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&arnumber=7041840
35	OFC/ NFOEC 2015	Ahmad Rostami, Kun Wang, Zere Ghebretensaé, Peter Öhlén and Björn Skubic	First Experimental Demonstration of Orchestration of Optical Transport, RAN and Cloud based on SDN	Mar-15	San Francisco California, USA	Industry, academic	https://www.osapublishing.org/abstract.cfm?uri=OFC-2015-Th5A.7
36	ONDM 2015	Anna Buttaboni, Marilet De Andrade, Massimo Tornatore, Achille Pattavina	Virtual PON Assignment for Fixed-Mobile Convergent Access-Aggregation Networks	May-15	Conferen ce, Pisa, Italy	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7127298
37	ITG Conference Photonic Networks	K. Grobe	WDM-PON with Wavelength-Routed ODN – Pros'n'Cons	May-15	Leipzig, Germany	Industry, academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7110082
38	IEEE Clodnet conference	Marilet De Andrade, Massimo Tornatore, Achille Pattavina, Ali Hamidian, Klaus Grobe	Cost Models for Baseband Unit (BBU) Hotelling: from Local to Cloud	May-15	Niagara Falls, Canada	Industry, academic	Not yet available

39	EuCNC 2015	Tahar Mamouni, Jose A. Torrijos Gijón, Péter Olaszi, Xavier Lagrange	Universal AAA for hybrid accesses	Jun-15	Paris, France	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7194107
40	EuCNC 2015	Thierno Diallo et al.[4]	A Complete Fronthaul CWDM Single Fiber Solution including Improved Monitoring Scheme	Jun-15	Paris, France	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7194092
41	EuCNC 2015	Ricard Vilalta, et. Al.	The Need for a Control Orchestration Protocol in Research Projects on Optical Networking	Jun-15	Paris, France	Industry + academic	http://www.cttc.es/publication/the-need-for-a-control-orchestration-protocol-in-research-projects-on-optical-networking/
42	EuCNC 2015	Z. Li, Y. Liu, J.C. Point, S. Ciftci, O. Eker, M. Savi, M. Tornatore, G. Verticale	Shared Cache as a Service in Future Converged Fixed and Mobile Network	Jun-15	Paris, France	Industry, academic	http://www.ict-combo.eu/data/uploads/img/events/eucnc_combo_jcpc-poster.pdf
43	HPSR 2015	Souheir Eido, MITHARWAL Pratibha, GRAVEY A., LOHR C.	MPTCP Solution for Seamless Local SIPTO Mobility	Jul-15	Budapest, Hungary	Industry+ Academic	https://portail.telecom-bretagne.eu/publi/htdocs/publi.jsp?id_publication=15350
44	ICTON 2015	Attila Mitcsenkov, Péter Ratkóczy, Tibor Cinkler	Minimal Cost Availability Improvement of Fixed Mobile Convergent (FMC) Access Networks: Diversification and Redundancy	Jul-15	Budapest, Hungary	Industry+ Academic	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=7193311
45	HPSR 2015	Y. Li, Y. Hadjadj-Aoul, P. Bertin, G.Rubino	Control Theory Based Interface Selection Mechanism in Fixed-Mobile Converged Network	Jul-15	Budapest, Hungary	Industry + academic	Not yet available
46	HPSR 2015	Z.Li, J.C.Point,S.Ciftci, O.Eker,M.Savi, G.Mauri, G. Verticale	ICN Based Shared Caching in Future Converged Fixed and Mobile Network	Jul-15	Budapest, Hungary	Industry, academic	http://goo.gl/7WEytu

[4] Full list of authors is hided 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 Abdelfattath, Christelle Aupetit-Berthelemot

47	HPSR 2015	A. Magee, S. Gosselin, D. Breuer, J. Torrijos, K.Grobe	A Modern Approach to Fixed Mobile Convergence on the Universal Access Gateway	Jul-15	Budapest, Hungary	Industry + academic	Not yet available
48	HPSR 2015	Younes Khadraoui, Xavier Lagrange, Stefan Höst, Thomas Monatt	On connection Control and Traffic Optimisation in FMC Networks	Jul-15	Budapest, Hungary	Industry+ Academic	Not yet available
49	ECOC 2015	Ricardo Martinez, Ricard Vilalta, Ramon Casellas, Raul Muñoz	Experimental Validation of a SDN Orchestrator for the Automatic Provisioning of Fixed and Mobile Services	Sep-15	Valencia, Spain	Industry + academic	http://goo.gl/yWhGR4
50	ECOC 2015	N. Carapellese, M. Tornatore, A. Pattavina, S. Gosselin	BBU Placement over a WDM Aggregation Network Considering OTN and Overlay Fronthaul Transport	Sep-15	Valencia, Spain	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6848838
51	NOF 2015	Moufida Feknous, Annie Gravey, Bertrand Le Guyader	Status Reporting versus Non Status Reporting Dynamic Bandwidth Allocation	Sep-15	Montreal, Canada	Industry + academic	https://portail.telecom-bretagne.eu/publi/htdocs/publi.jsp?id_publication=15569
52	CCNC 2016	Y. Khadraoui, X.Lagrange, A. Gravey	Performance analysis of LTE-WiFi very tight coupling	Jan-16	Las Vegas,US	Industry+ Academic	Not yet available

Table 1 - Peer-reviewed technical papers in international conferences

3.3 Invited technical papers in conferences

COMBO experienced 11 invited papers during two reporting periods 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 few ones presented by AITIA and POLIMI.

Among technical areas, “C - RAN design enabling FMC” was the most demanded one with 6 papers, followed by “A - FMC Network architectures & NG-PoP concept” and “E - Optical Access Network design for FMC” with 4 and 3 papers respectively (some of papers for cross-topic). Following table reports on invited conference papers in details:

№	Name of event	Author(s)	Title	Period	Place	Type of audience	URL to publisher
1	LTE World Summit 2013	Anna Pizzinat	C-RAN architecture and fronthaul challenges	Jun-13	Amsterdam, Netherlands	Industry + academic	www.lteconference.com/world
2	Broadband World Forum 2013	Anna Pizzinat	Perspectives on mobile fronthaul	Oct-13	Amsterdam, Netherlands	Industry + academic	www.broadbandworldforum.com
3	LTE World Summit 2014	Philippe CHANCLOU, Anna PIZZINAT	Fronthaul challenges	Jun-14	Amsterdam, Netherlands	Industry + academic	http://lteworldsummit.com/
4	ECOC 2014	Anna Pizzinat	Things you should know about fronthaul	Sep-14	Cannes, France	Industry + academic	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6964214
5	Broadband World Forum 2014	Anna Pizzinat	What is the architecture of future connectivity	Oct-14	Amsterdam, Netherlands	Industry + academic	www.broadbandworldforum.com
6	OFC/NFOEC 2015	Stéphane Gosselin et al.[5]	Fixed and Mobile Convergence: Which Role for Optical Networks?	Mar-15	Los Angeles, USA	Industry + academic	http://www.opticsinfobase.org/viewmedia.cfm?URI=OFC-2015-Th3H.2&seq=0
7	ONDM 2015	S. Pachnicke, M. Eiselt, K. Grobe J.-P. Elberns	The Frontiers of Optical Access Networks	May-15	Conference, Pisa, Italy	Industry + academic	http://dx.doi.org/10.1109/ONDM.2015.7127266
8	ICTON 2015	Julio Montalvo, Marta Arroyo, José A. Torrijos, Francisco J. Lorca, Ignacio Berberana	Fixed-Mobile Convergence and Virtualization in 5G optical transport networks	Jul-15	Conference, Budapest, Hungary	Industry + academic	http://www.itl.waw.pl/icton2015-presentations#5GT

[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

9	ICTON 2015	D. Breuer, E. Weis	Assessment of Future Backhaul and Fronthaul Networks for HetNet Architectures	Jul-15	Conference, Budapest, Hungary	Industry + academic	http://ieeexplore.ieee.org/xpl/conhome.jsp?punumber=1000766
10	HPSR 2015	Péter Olaszi et al.[6]	Fixed-mobile Convergence: Architecture and Functionality	Jul-15	Budapest, Hungary	Industry + academic	Not yet available
11	ACP 2015	A. Pattavina	Next generation convergent access/aggregation networks	Nov-15	Hong Kong	Industry + academic	Not yet available

Table 2 - Invited technical papers in conferences

3.4 Technical papers in international journals or magazines

Altogether, COMBO project has published 10 journal papers on variety of FMC-related topics. As already mentioned, additional two sub-divisions are introduced for the group of journal papers. Following sub-chapters describe those.

3.4.1 Peer-reviewed technical papers in international journals or magazines

From those 10, 7 papers are regular peer-reviewed journal papers, which are reporting on “A - FMC Network architectures & NG-PoP concept” (3 papers), “B - Energy efficiency and green benefit of FMC” (2 papers) and “E - Optical Access Network design for FMC” (2 papers).

[6] Full list of authors is hided 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

№	Name of journal	Author(s)	Title	Period	URL to publisher
1	Journal of Lightwave technology (JLT)	Massimo Tornatore	A Multi-Threaded Dynamic Bandwidth and Wavelength Allocation Scheme With Void Filling for Long Reach WDM/TDM PONs	Apr-13	http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6417938
2	Journal on Selected Areas on Communications	M. Tornatore	Energy Efficient BaseBand Units (BBU) Placement in a Fixed/Mobile Converged WDM Aggregation Network	Aug-14	http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6848838
3	Photonics Journal, MDPI	Paola Garfias, Marilet De Andrade, Massimo Tornatore, Anna Buttaboni, Sebastià Sallent, Lluís Gutiérrez	Energy-saving mechanism in WDM/TDM-PON based on upstream network traffic	Aug-14	http://www.mdpi.com/journal/photonics
4	Journal of Advances in Computer Networks	FEKNOUS Moufida Rebiha, LE GUYADER Bertrand, GRAVEY Annie	Revisiting Access and Aggregation Network Architecture	Sep-14	https://portail.telecom-bretagne.eu/publi/htdocs/publi.jsp?id_publication=14341
5	Optical Switching and Networking Journal	Marilet De Andrade, Anna Buttaboni, Massimo Tornatore, Pierpaolo Boffi, Paolo Martelli, Achille Pattavina	Optimization of Long-Reach TDM/WDM Passive Optical Networks	Nov-14	http://ees.elsevier.com/osn/default.asp
6	Journal of Optical Communications and Networking (JOCN)	Lida Sadeghioon, Annie Gravey, Bogdan Uscumlic, Philippe Gravey, Michel Morvan	A Full Featured and Lightweight Control for Optical Packet Metro Networks	Feb-15	https://www.telecom-bretagne.eu/publications/publication.php?idpublication=14760
7	Advances in Computer Science : an International Journal	Moufida Feknous, Bertrand Le Guyader, Pal Varga, Annie Gravey, Stéphane Gosselin, Jose Alfonso Torrijos Gijon	Multi-Criteria Comparison Between Legacy and Next Generation Point of Presence Broadband Network Architectures	May-15	http://goo.gl/lQkuei

Table 3 - Peer-reviewed technical papers in international journals or magazines

3.4.2 Invited technical papers in international journals or magazines

Moreover, COMBO was invited to publish 3 journal papers (among which 2 are published and 1 is awaiting for publication). Partners Orange and ADVA were involved in this activity, which is described in table below:

№	Name of journal	Author(s)	Title	Period	URL to publisher
1	Journal of Lightwave technology (JLT)	K. Grobe	Access Networks based on Tunable Lasers	Mar-14	http://dx.doi.org/10.1109/JLT.2014.2312433
2	Journal of Lightwave technology (JLT)	Anna Pizzinat, Philippe Chanclou, Fabienne Saliou, and Thierno Diallo	Things you should know about fronthaul	Mar-15	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7009970
3	Journal of Optical Communications and Networking (JOCN)	Stéphane Gosselin, Anna Pizzinat, Xavier Grall, Dirk Breuer, Eckard Bogenfeld, Sandro Krauß, Jose Torrijos Gijón, Ali Hamidian, Neiva Fonseca, and Björn Skubic	Fixed and Mobile Convergence: Which Role for Optical Networks?	Oct-15	Not yet available

Table 4 - Invited technical papers in international journals or magazines

3.4.3 Submitted (pending) technical papers in international journals or magazines

Two papers (one of which is invited) are submitted and pending notice from committee currently. Those journal papers are:

№	Name of event, journal or activity	Author(s)	Title
1	Journal of Lightwave technology (JLT)	S. Pachnicke, J. Zhu, M. Lawin, M. H. Eiselt, S. Mayne, B. Quemeneur, D. Sayles, H. Schwuchow, A. Wonfor, P. Marx, M. Fellhofer, P. Neuber, M. Dietrich, M. J. Wale, R.V. Penty, I. H. White, J.-P. Elbers	Tunable WDM-PON System with Centralized Wavelength Control[7]
2	Computer Networks (Journal, Elsevier)	M. Savi, M. Tornatore, G. Verticale	Performance Evaluation of Video Servers Replication in Metro/Access Networks

Table 5 - Submitted (pending) technical papers in international journals or magazines

[7] Invited

3.4.4 Invited FSAN JOCN 2-part paper on NG-PON2

With the publication expected in the end of 2015, Journal of Optical Communications and Networking (JOCN) will issue 2-part invited paper on Physical Layer Aspects of NG-PON2 Standards. This paper is not sole outcome of the COMBO project, however is co-authored by one of COMBO Consortium Partners (Klaus Grobe, ADVA) and thus was partly influenced by the COMBO outcomes.

3.4.4.1 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.

3.4.4.2 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.

3.4.4.3 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, main COMBO results on integration of fronthaul and backhaul with fixed access will be presented at an FSAN workshop during 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 signaling 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.

3.5 Keynote speeches at international conferences

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

№	Name of event	Author(s)	Title	Period	Place	URL to publisher
1	ONDM 2013	S. Gosselin	Towards Green and Convergent Broadband Networks	Apr-13	Brest, France	http://conferences.telecom-bretagne.eu/ondm2013/keynote-speakers/
2	ITG Conference on Photonic Networks	K. Grobe	Next-Generation Access/Backhaul based on ITU G.989, NG-PON2 (Keynote)	May-14	Leipzig, Germany	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6839965
3	ITG-Conference "Photonic Networks"	S. Pachnicke, A. Magee, P. Turnbull, K. Grobe, J.-P. Elbers	Functional and Structural Convergence of Fixed/Mobile Access Networks	May-15	Leipzig, Germany	http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7110076

Table 6 - Keynote speeches at international conferences

3.6 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 12 activities to be mentioned under this category, whereas majority of them (7) were presented in the area of “A - FMC Network architectures & NG-PoP concept”. Table below shows that in details:

№	Name of event	Author(s)	Title	Period	Place	Type of audience	URL to publisher
1	MPLS World Congress 2013	Anthony Magee	MPLS & SDN Intersections	Mar-13	Paris, France	Industry + academic	http://www.uppersideconferences.com/mpls2013/mpls2013program_day_1.html
2	Seminar at University of California, Davis	M Tornatore	The Role of Optical Networks in the Big Data Era	Apr-13	Davis, CA, USA	Academic	http://seminars.cs.ucdavis.edu/?type=1&when=past
3	Seminar at University of California, Davis	M Tornatore	Energy Efficient BaseBand Units (BBU) Placement in a Fixed/Mobile Converged WDM Aggregation Network	Apr-13	Davis, CA, USA	Academic	http://networks.cs.ucdavis.edu/postofc2014.html/networks.cs.ucdavis.edu/postofc2014.html
4	FuNeMS 2013	D. Breuer, S. Gosselin, J. Torrijos, J.-C. Point	Challenges in mutualization of Fixed and Mobile networks	Jul-13	Lisbon, Portugal	Industry + academic	Not applicable
5	OFC/NFOEC 2014	Anna Pizzinat	How D-RoF has Established as the Natural Choice for Mobile Front-haul Transport;	Mar-14	San Francisco (CA)	Industry + academic	Not applicable
6	Cloud RAN 2014	Thierno Diallo, Anna Pizzinat, Philippe Chanclou, F. Saliou, F. Deletre, C. Aupetit-Berthelemot	Jitter Impact on Radio Frequency Accuracy Budget in C-RAN Architecture	May-14	Paris, France	Industry + academic	http://www.uppersideconferences.com/cloudran2014/cloudran2014intro.html
7	New Telecom Network Architectures for the Cloud Era	Massimo Tornatore	New Telecom Network Architectures for the Cloud Era An inter EU-projects workshop	Jun-14	Milan, Italy	Industry + academic	http://noc2014.deib.polimi.it/?page_id=1716
8	EuCNC 2014	Jean-Charles Point, Stefano Bregni, Achille Pattavina	Fixed-Mobile Convergent Networks: Solutions and Architectures Proposed in FP7	Jun-14	Bologna, Italy	Industry + academic	Not applicable
9	EuCNC 2014	Stephane Gosselin	COMBO – Network scenarios for Fixed Mobile Convergence	Jun-14	Bologna, Italy	Industry + academic	Not applicable

10	Seminar at Trinity College Dublin	M Tornatore	Optical access/aggregation architectures for Centralized Radio Access Networks (C-RANs)	May-15	Dublin, Spain	Academic	http://seminars.cs.ucdavis.edu/?type=1&when=past
11	EuCNC 2015	Stéphane Gosselin, Dirk Breuer, Sandro Krauss, Jose Torrijos, Ali Hamidian	Unified Network Architecture Integrating Back/Front-hauling with Fixed Access	Jun-15	Paris, France	Industry + academic	http://www.eucnc.eu/?q=node/118
12	ECOC 2015	S.Pachnicke	NFV-based Universal Access for converged fixed and mobile broadband access/aggregation networks	Sep-15	Valencia , Spain	Industry + academic	Not applicable

Table 7 - Presentations at workshops or panels

3.7 Educational activities

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

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

A tutorial session, led by COMBO partner AITIA International, Inc. (Hungary) entitled "Fixed-mobile Convergence: Architecture and Functionality" was organized at IEEE HPSR 2015. It consisted of 4 subsections („Introduction to fixed-mobile convergence", „Structural convergence", „Functional convergence" and „Summary and look-ahead") and gave a comprehensive overview of COMBO assumptions and findings playing the role in the design of future-proof converged networks.

Figure 7 - Péter Olaszi (AITIA), Annie Gravey (IT-TB) and Björn Skubic (EAB) at IEEE HPSR 2015 tutorial session

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[8] 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:

```
1        Introduction
1.1      Historical overview [Slides][Video]
1.2      The COMBO prespective [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 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 modeling [Slides][Video]
3.8      Preliminary results [Slides][Video]
4        Summary and conclusion [Slides][Video]
```

Figure 8 – FMS tutorial on COMBO website

[8] http://www.ict-combo.eu/index.php?id=fmc-tutorial-2015

3.7.2 Editing of book for Springer "Optical Networks" series

This is ongoing activity which has not been published yet, however significant work has already been done (the book chapter collected and submitted to the publisher for final check and formatting). This book yield 14 chapters (three of which directly contributed from project partners) that investigate new enabling technologies for Fi-Wi (fiber-wireless) convergence. Fi-Wi technologies will be 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 will be:

- System level: Radio over Fiber (digitalized vs. analogic, 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.

The book will be 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 (ALU[9], POLIMI, ORANGE) that will promote the COMBO vision in the larger context of Fi-Wi convergence.

3.7.3 Open Online Education

The French government launched in 2014 a portal with an access to several Massive Open OnLine Course (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 realized a video to explain the objectives of fixed-mobile convergence and why convergence is a major issue for 5G networks. The first lesson will start on November 5th, 2015.

[9] Exited project at Month 21

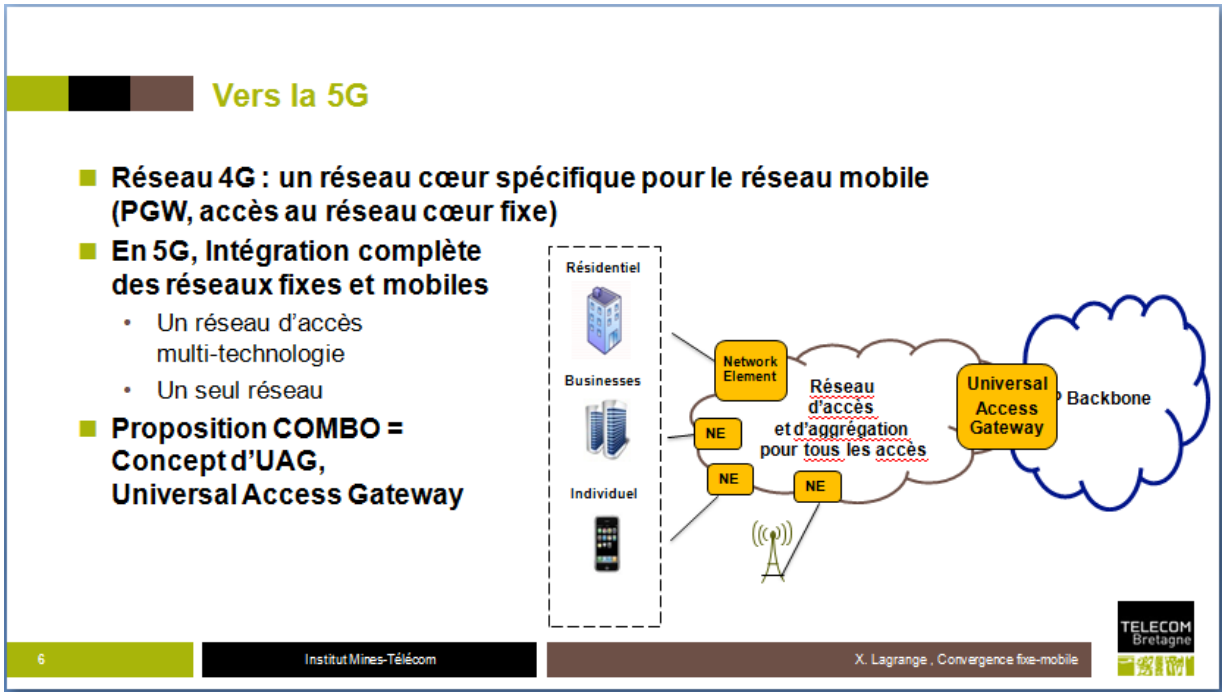


Figure 9 – Screenshot of the slide from Mooc video

3.7.4 Webinars

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

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

3.7.5 Inclusion of COMBO results into educational materials of academia partners

Apart from Open Online Education reported in 3.7.3, academic Partners from COMBO Consortium has included outcomes of the project into their lectures and courses. Few examples are:

- 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 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 if 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.

3.8 Collaboration with other initiatives

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

- Collaboration with FP7 projects and international/national initiatives/technology platforms;
- Collaboration with H2020 5G-PPP initiative projects;
- Joint events with other initiatives.

3.8.1 Collaboration with FP7 projects and international/national initiatives/technology platforms

Collaboration with those projects 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:

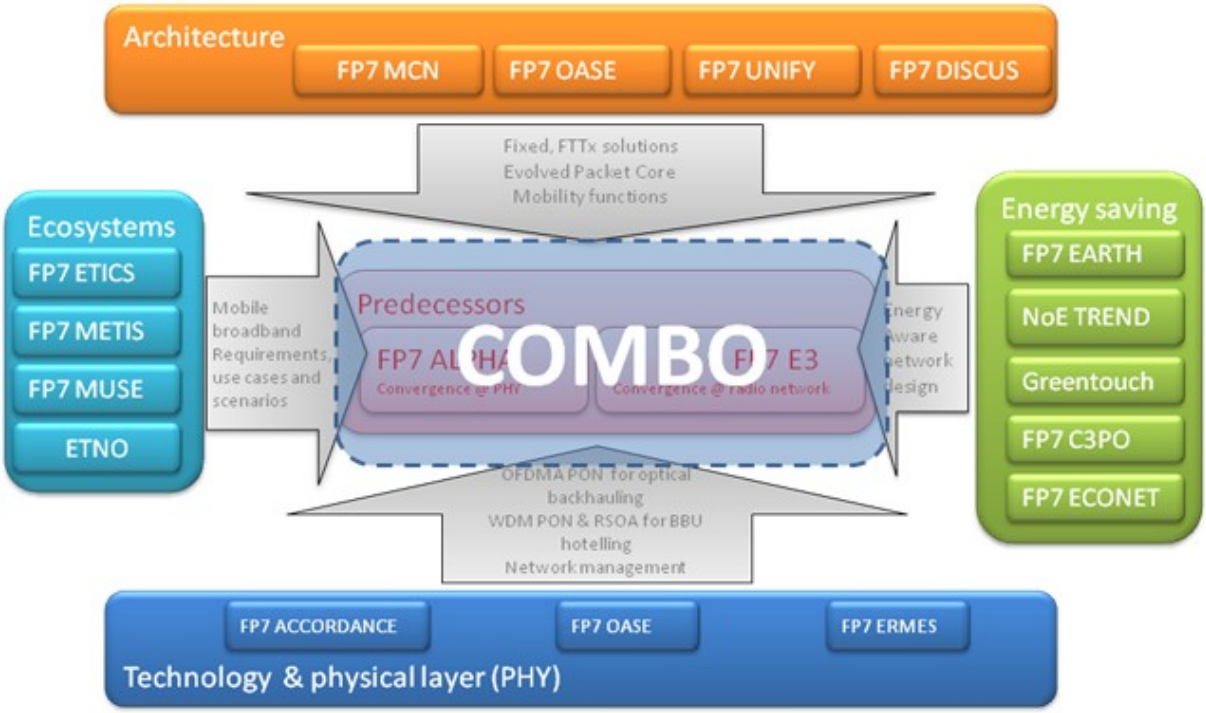


Figure 10 – Principle of uptake of results from other initiatives by COMBO

More particularly, actual collaboration was going on with 14 projects in all 5 technological areas[10], summarized in the following table:

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

Table 8 – Uptake of other projects results into COMBO research

[10] See section 3.1 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 did participate to these FP7 projects (as for OASE, ERMES, METIS, MCN, DISCUS to name a few). In addition, closer collaboration was built with some few 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 [2].

It also should be noted, that COMBO presented a joint paper[11] 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 and current work of COMBO, DISCUS and iJOIN regarding the promising network architectures with the potential to support the transport of 5G services.

3.8.2 Collaboration with H2020 5G-PPP initiative projects

This is the most recent collaboration endeavour, due to the fact that these projects were started only in July 2015 or later. However, COMBO undertook thorough analysis of those 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):

- XHAUL (http://5g-ppp.eu/xhaul/) – front-/back-/mid-haul architecture and design for 5G;
- 5Gex (http://5g-ppp.eu/5gex/) - development of an open platform based on NFV/SDN for cross-domain orchestration;
- 5G-Xhaul (http://5g-ppp.eu/5g-xhaul/) – dynamically reconfigurable converged optical and wireless network solution able to flexibly connect Small Cells to the core network;
- CHARISMA (http://5g-ppp.eu/charisma/) - cloud infrastructure platform for secured, low-latency converged wireless/wireline advanced 5G networking.

[11] „Fixed-Mobile Convergence and Virtualization in 5G optical transport networks“, Julio Montalvo, Marta Arroyo, José A. Torrijos, Francisco J. Lorca, Ignacio Berberana, ICTON 2015

At the time of writing these rows (September 2015) COMBO has already presented COMBO to CHARISMA project and contacted other projects in order to arrange presentations and agree on collaboration fields more precisely.

It should be also explicitly noted, that COMBO is also officially one of the "feeding" projects of 5G-PPP[12]. 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"[13].

3.8.3 Joint events with other initiatives

Several workshops and panels occurred, some of which were organized by COMBO, occasionally in collaboration with other initiatives:

1. Special session called "COMBO: Fixed Mobile Convergence"[14] was organized at the European Wireless 2014 conference (EW 2014), Barcelona, Spain, 14-16 May 2014

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

2. Workshop called "New Telecom Network Architectures for the Cloud Era"[15] at the 19th IEEE European Conference On Network And Optical Communications (IEEE NOC 2014), Milano, Italy, 4-6 June 2014

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

3. Workshop "Fixed-Mobile Convergent Networks: Solutions and Architectures Proposed"[16] at the European Conference on Networks and Communications, (EuCNC 2014), Bologna, Italy, 23-26 June 2014

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

4. Workshop "Is NG-PON2 an ultimate access solution? Is there anything coming afterwards?"[17] at the 40th European Conference on Optical Communication (ECOC 2014), Cannes, France, 21-25 Sept. 2014

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

[13] Section 7.3.3 in: https://www.ngmn.org/uploads/media/NGMN_RANEV_D2_Further_Study_on_Critical_C-RAN_Technologes_v1.0.pdf

[14] http://www.ew2014.org/workshop-program.html#A4

[15] http://noc2014.deib.polimi.it/?page_id=1716

[16] http://www.eucnc.eu/2014/www.eucnc.eu/indexcb94.html?q=node/116

[17] http://www.ecoc2014.org/sunday-workshops.html

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)[18], Munich. Germany, 9-10 of November 2015

   This workshop is organized by COMBO project and currently (as of September 2015) is finalizing preparation. The workshop will have a total of 7 papers and echange of information between 5 projects (COMBO, ICIRRUS, 5G-XHAUL, CHARISMA, XHAUL).

6. Workshop "SDN & NFV: Real value with new business opportunities or research hype with unmanageable complexity?"[19] at 41st European Conference on Optical Communication (ECOC 2015) in Valencia, Spain, 27 Sept – 1 Oct, 2015

   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.

3.9 Other dissemination activities

Very extensive coverage in Turkish press was organized by Partner ARGELA prior to project 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://www.milliyet.com.tr/turk-telekom-teknoloji-devlerini-teknoloji-2094774/
- http://www.hurriyet.com.tr/teknoloji/29682732.asp
- http://www.aksam.com.tr/sirketlerden/turk-telekom-gelecege-yatirim/haber-427538
- http://haber.star.com.tr/ekonomi/turk-telekom-teknoloji-devlerini-istanbulda-bulusturacak/haber-1047081
- http://www.yenisafak.com/teknoloji/telekom-devleri-istanbulda-186476
- http://www.aa.com.tr/tr/sirket-haberleri/gundem/5957700
- http://shiftdelete.net/teknoloji-devleri-5g-icin-istanbulda-62693
- http://finans.haberler.com/219949-araci-kurum-raporlari/

[18] http://www.ctte-conference.com/?q=node/231

[19] http://www.ecoc2015.org/modules.php?name=webstructure&idwebstructure=26

- http://www.techno-labs.com/turk-telekom-grubu-abnin-teknoloji-devlerini-5g-icin-istanbulda-bulusturacak/
- http://www.fortuneturkey.com/turk-telekom-teknoloji-devlerini-bulusturacak-17002

TECHNOLABS

Haber | Donanım | Mobil | Yazılım | Oyun | İnternet | ASUS | TechnoTV | Galeriler | Ara

Türk Telekom Grubu AB'nin teknoloji devlerini 5G için İstanbul'da buluşturacak

Yazar: Techno Labs Tarih: 30 Temmuz 2015 Perşembe

Türkiye'de yeni nesil iletişim teknolojisinin öncüsü olan Türk Telekom Grubu, ülkemizi 5G'nin gelişimi konusunda uluslararası arenada temsil etmeye devam ediyor.

Türkiye, dünyadaki teknoloji gündeminin ana konularından biri olan 5G konusunda Türk Telekom Grubu'nun katkılarıyla önemli bir toplantıya ev sahipliği yapmaya hazırlanıyor. Türk Telekom Grubu, dünyada 5G teknolojisinin gelişiminde yol haritasını belirleyecek en önemli girişimlerden biri olarak kabul edilen Avrupa Birliği COMBO Projesi'nde Türkiye'yi temsil ederek, ülkemizde 5G teknolojisinin gelişimine de öncülük edecek. Türk Telekom Grubu COMBO Projesi'ne grup şirketi ARGELA ile katılacak.

Galeriler

Mükemmeliyetçi ruhları coşturacak fotoğraflar

Mükemmeliyetçi insanlar bilirler, hayatın küçüklü büyüklü kusurları arasında bazen mucizeler olur ve "Mükemmel" detaylar göze...

Meizu MX5 ile çekilen 20 fotoğraf!

Meizu MX5'in kamera kalitesini merak edenler, bu cihazla çekilen 20 fotoğrafı yakından incelemeli Türk akıllı...

Muhteşem minimal mimari fotoğraflar

Figure 11 – Article about COMBO and 5G in Turkish press

3.10 Collaborative publications

This chapter explicitly exposes 19 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 those papers are already mentioned in sections 3.2 - 3.4, 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.

№	Name of conference or journal	Author(s)	Title	Date/ Period	Place
1	OFC/NFOEC 2013	D. Breuer, E. Weis, S. Gosselin, T. Mamouni, J. Torrijos	Unified Access and Aggregation Network Allowing Fixed and Mobile Networks to Converge	Mar-13	Anaheim, USA
2	ICC2013	Julio Araujo, Frederic Giroire, Yaning Liu	Energy Efficient Content Distribution	Jun-13	Budapest, Hungary
3	FuNeMS 2013	S. Gosselin, T. Mamouni, P. Bertin, J. Torrijos, D. Breuer, E. Weis, J.-C. Point	Converged fixed and mobile broadband networks based on Next Generation Point of Presence	Jul-13	Lisbon, Portugal
4	FuNeMS 2013	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	Optical fiber solution for mobile fronthaul to achieve Cloud Radio Access Network	Jul-13	Lisbon, Portugal
5	EW2014	S. Gosselin, J. De Biasio, M. Feknous, T. Mamouni, J. Torrijos, L. Cucala, D. Breuer, E. Weis, F. Geilhardt, D. v. Hugo, E. Bogenfeld, A. Hamidian, N. Fonseca, Y. Liu, S. Kuehrer, A. Gravey, A. Mitcsenkov, J.V. Galán, E. Masgrau, L. Gómez, L. Alonso, S. Höst, A. Magee	Fixed and Mobile Convergence: Needs and Solutions	May-14	Barcelona, Spain
6	ISCC2014	M.Feknous, T.Houdoin, B.Le Guyader, J.De biasio, A.Gravey, Jose Torrijos	Internet Traffic Analysis: A Case Study From Two Major European Operators	Jun-14	Madeira, Portugal
7	Photonics Journal, MDPI	Paola Garfias, Marilet De Andrade, Massimo Tornatore, Anna Buttaboni, Sebastià Sallent, Lluís Gutiérrez	Energy-saving mechanism in WDM/TDM-PON based on upstream network traffic	Aug-14	Not applicable
8	OFC/NFOEC 2015	Stéphane Gosselin, Anna Pizzinat, Xavier Grall, Dirk Breuer, Eckard Bogenfeld, Jose Torrijos Gijón, Ali Hamidian, Neiva Fonseca	Fixed and Mobile Convergence: Which Role for Optical Networks?	Mar-15	Los Angeles, USA
9	Advances in Computer Science: an International	Moufida Feknous, Bertrand Le Guyader, Pal Varga, Annie Gravey, Stéphane Gosselin, Jose Alfonso Torrijos Gijon	Multi-Criteria Comparison Between Legacy and Next Generation Point of Presence Broadband Network Architectures	May-15	Not applicable

	Journal				
10	IEEE CLOUDNET conference	Marilet De Andrade, Massimo Tornatore, Achille Pattavina, Ali Hamidian, Klaus Grobe	Cost Models for Baseband Unit (BBU) Hotelling: from Local to Cloud	May-15	Niagara Falls, Canada
11	EuCNC 2015	Tahar Mamouni, Jose A. Torrijos Gijón, Péter Olaszi, Xavier Lagrange	Universal AAA for hybrid accesses	Jun-15	Paris, France
12	EuCNC 2015	Z. Li, Y. Liu, J.C. Point, S. Ciftci, O. Eker, M. Savi, M. Tornatore, G. Verticale	Shared Cache as a Service in Future Converged Fixed and Mobile Network	Jun-15	Paris, France
13	HPSR 2015	Z. Li, J.C. Point, S. Ciftci, O. Eker, M. Savi, G. Mauri, G. Verticale	ICN Based Shared Caching in Future Converged Fixed and Mobile Network	Jul-15	Budapest, Hungary
14	HPSR 2015	A. Magee, S. Gosselin, D. Breuer, J. Torrijos, K.Grobe	A Modern Approach to Fixed Mobile Convergence on the Universal Access Gateway	Jul-15	Conference, Budapest, Hungary
15	HPSR 2015	Péter Olaszi, Dirk Breuer, Tibor Cinkler, Stéphane Gosselin, Annie Gravey, Ali Hamidian, Stefan Höst, Tahar Mamouni, Stephan Pachnicke, Björn Skubic, Jose Torrijos Gijón	Fixed-mobile Convergence: Architecture and Functionality	Jul-15	Budapest, Hungary
16	HPSR 2015	Younes Khadraoui, Xavier Lagrange, Stefan Höst, Thomas Monatt	On connection Control and Traffic Optimisation in FMC Networks	Jul-15	Budapest, Hungary
17	ECOC 2015	Nicola Carapellese, Massimo Tornatore, Achille Pattavina, Stephane Gosselin	BBU Placement over a WDM Aggregation Network Considering OTN and Overlay Fronthaul Transport	Sep-15	Valencia, Spain
18	Journal of Optical Communications and Networking	Stéphane Gosselin, Anna Pizzinat, Xavier Grall, Dirk Breuer, Eckard Bogenfeld, Sandro Krauß, Jose Torrijos Gijón, Ali Hamidian, Neiva Fonseca, and Björn Skubic	Fixed and Mobile Convergence: Which Role for Optical Networks? (journal version)	Oct-15	Not applicable
19	CCNC 2016	Younes Khadraoui, Xavier Lagrange, Annie Gravey	Performance analysis of LTE-WiFi very tight coupling	Jan-16	Las Vegas, USA

4 Standardization activities performed during considered period

As for the dissemination activities the starting point for the standardization activities was identifying the technical areas of the project subject to generate results to be standardized.

The technical areas, which were tentatively formulated by the Consortium are reminded here next:

- 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

Once these technical areas have been identified, the next step which was taken was to identify the standard organizations which cover the identified technical areas.

Thus, the targeted SDOs are the following ones;

- European Telecommunications Standards Institute (ETSI)
- The 3rd Generation Partnership Project (3GPP)
- Broadband Forum (BBF)
- Full Service Access Network (FSAN)
- International Telecommunication Union – Telecommunication Standardization Sector (ITU-T)

In addition to the list of targeted SDOs there is a list of “candidate” organizations regrouping standard organizations, industry alliances, industry forums and others. This list presented below and is mainly used for pre standardization activities.

- Next Generation Mobile Networks Alliance (NGMN)
- Open Mobile Alliance (OMA)
- Wi-Fi Alliance
- Wireless Broadband Alliance (WBA)
- Institute of Electrical and Electronics Engineers (IEEE)
- Metro Ethernet Forum (MEF)
- Internet Research Task Force (IRTF)

An important criterion for the selection of the above mentioned organizations was the involvement of the Combo Consortium members in these standard organizations. Thus, only those organizations in which Combo partners have standardization departments strongly involved have been considered.

As methodology for fulfilling the standardization activities goals two approaches have been defined and implemented in the project.

Top-down approach: is an agile and proactive approach for bringing technical innovations to standardization groups. The principle consists in creating frameworks in excising SDOs (e.g. 3GPP Work Item / Study Item, ETSI ISG, BBF Working Text) in which to develop COMBO Innovations.

Bottom-up approach: is a stepwise approach for identifying opened work items, study items, working texts, working tasks, etc. within the key standardization groups for FMC and to assess the standardization contribution opportunity of the COMBO project in a given standardization framework. The three steps of this approach are as follows:

- Step 1: identifying the candidate SDOs and study items for FMC innovations
- Step 2: monitor the SDO for contribution opportunities
- Step 3 : submit relevant contribution to the identified SDO

Finally, a **Standardization Dashboard** was implemented in the project in order to log all the task related to the top down and bottom up approaches.

4.1 Standardization activities following the top down approach

This section captures the main achievements made following the top down approach.

3GPP-BBF Common functions:

Contribution topic	SDO	SDO Framework	SDO Reference	Timeline	Status	Action	COMBO technical area
3GPP-BBF Common functions	BBF	joint BBF - 3GPP work	SD-357	2015 Q1 - 2016 Q2	open	Contributing	FMC Network archictures and NG-PoP concept

Abstract: This Study Document (SD-357) aims at identifying and characterizing a set of common function. This should be done especially using information from BBF TR-300 and TR-290. Depending on how it progresses, a liaison to invite 3GPP to initiate a common work may be sent in the future.

Contributions from COMBO: Combo partners have contributed to 3GPP TS 23.401 and BBF TR-101 functions (bbf2015.589.01) standard documents.

FMC [COMBO vision] position in 5G global initiative launched by NGMN Alliance

Contribution topic	SDO	SDO Framework	SDO Reference	Timeline	Status	Action	COMBO technical area
FMC [=COMBO vision] position in 5G global initiative launched by NGMN Alliance	NGMN Alliance	5G white paper - workstream WS3 on "Technology & architecture"		2014	accomplished	Contributing	FMC Network archictures and NG-PoP concept

Abstract: The Next Generation Mobile Networks Alliance published in February 2015 a white paper regarding the future 5G mobile systems. This white paper includes the operator requirements intended to guide the development of 5G systems and related standards.

Relation with COMBO: NGMN 5G white paper is of COMBO interest as it specifies the view of mobile telecom operators on future 5G systems. The 5G vision and requirements will be used in COMBO to verify that FMC networks developed in WP3 are compatible with future 5G mobile networks

Contributions from COMBO: Orange, DT and Telefonica are members of the NGMN board and have participated in the 5G white paper. Although COMBO members from these companies have not contributed directly to the 5G white paper, they have pushed FMC concepts to be included in this white paper through their direct contact to the different standardization organization of Orange, DT and Telefonica. As a matter of fact, NGMN identified network-level FMC in the 5G design principles. NGMN 5G White Paper, version 1.0, February 2015, https://www.ngmn.org

Hybrid access

Contribution topic	SDO	SDO Framework	SDO Reference	Timeline	Status	Action	COMBO technical area
Hybrid access	BBF	FMC use case	WT-348	2014 Q3 - 2016 Q1	in progress	Contributing	FMC Network archictures and NG-PoP concept

Abstract: Inspired by the COMBO vision this contribution aims at defining use cases for FMC within BBF. Taking benefit of nearby LTE antennas to complement poor bandwidth DSL accesses is currently referred to as “Hybrid access”. Working Text 348 aims at defining an architectural framework and the associated technical requirements to implement hybrid access on deployed networks. Solutions always imply an hybrid CPE and sometimes imply a aggregation/distribution function inside the network.

Contributions from COMBO: Proposed text for section 4: Use Cases (bbf2014.1153.00), Common Requirements (bbf.2015.158.01), Hybrid access at the IETF (bbf2015.244.00); HAG bypass option for packet-based distribution (bbf2015.504.01)

RADIUS Attributes Catalog

Contribution topic	SDO	SDO Framework	SDO Reference	Timeline	Status	Action	COMBO technical area
RADIUS Attributes Catalog	BBF	RADIUS common set of attributes for FMC	WT-341	2014 Q1 - 2015 Q4	in progress	Contributing	FMC Network archictures and NG-PoP concept

Abstract: This Working Text aims at cataloging RADIUS attributes used in fixed access networks. The outcome of this work could be the standardization of VSAs and comparison of the catalog content with Diameter attributes used in 3GPP networks. Note: The success of this work mainly relies on vendors willingness to cooperate.

Contributions from COMBO: Authentication attributes (bbf2014.1152.00), New attributes for section 4 (bbf2015.159.03); Draft for IETF radext WG (bbf2015.582.01)

How does Passive Optical Network tackle Radio Access Network evolution?

Contribution topic	SDO	SDO Framework	SDO Reference	Timeline	Status	Action	COMBO technical area
How does Passive Optical Network tackle Radio Access Network evolution?	FSAN	White Paper - Operators		2015 Q1 - 2015 Q4	in progress	Leading	Optical Access Network design for FMC

Abstract: Traditional Radio Access Network (RAN) architecture will need to evolve to support centralized interference management required by complex heterogeneous networks. In addition, the multiplication of antenna ports raises new challenges in terms of network coordination and energy efficiency. Cloud-RAN (C-RAN) is an attractive architecture to cope with these issues and also offers potential benefits for site installation. It is thus important for optical access to express a clear view of the potential interfaces and transmission systems that C-RAN needs to connect base station processing units to RF blocks. For these reasons, FSAN operators took the initiative to analyse optical network scenarios for C-RAN use cases. This white paper is edited by Orange, China Unicom, China Telecom, Telecom Italia, NTT, Portugal Telecom, KDDI and led by Orange.

Relation with COMBO: This white paper is fully in line with COMBO work on possible integration of fronthaul and backhaul with fixed access networks. Since some of the integration scenarios proposed by COMBO rely on NG-PON2, it is important that FSAN can fully benefit from COMBO results on this field. Relation is made through a COMBO contributor who is also the FSAN delegate who leads this white paper.

Contributions from COMBO: COMBO brings contributions to this white paper on optical network scenarios for C-RAN and also on system requirements for fronthaul. Version 8.0 of the white paper has been produced in August 2015 and is currently being discussed within FSAN.

Universal Access Gateway

Contribution topic	SDO	SDO Framework	SDO Reference	Timeline	Status	Action	COMBO technical area
UAG	ETSI	White Paper		2015 Q3	accomplished	Leading	FMC Network archictures and NG-PoP concept

Abstract: The Universal Access Gateway is a key concept in Fixed Mobile Convergence vision of the COMBO project. The white paper presents the functional architecture of the UAG and the main challenges that have to be taken on for deploying the UAG in operators' network. The main goal of the white paper is (i) introducing the concept to the industry and (ii) triggering discussions for setting the framework for the pre standardization work that is required prior of making the UAG a standard based network node.

Relation with COMBO: The white paper was issued by the COMBO project with the main goal of creating a momentum in the industry for setting up an ETSI ISG on the UAG topic. The pre standardization work planned in the ISG aims at setting up the floor for the standardization work in 3GPP and BBF SDOs.

Fronthaul & Centralized RAN Evolution

Contribution topic	SDO	SDO Framework	SDO Reference	Timeline	Status	Action	COMBO technical area
Fronthaul & Centralized RAN Evolution	operator initiative	White Paper	none	2015 Q1 - 2015 Q4	in progress	Leading	RAN design enabling FMC

Abstract: "The key objective of this white paper is to animate the debate and accelerate the market development of interoperable fronthaul solutions. In this white paper, signatories ask for a joint action involving mobile network industries, standards development organizations and network operators by the following steps:

- Analyze the pros and cons of the different architectures & transport solutions for inter-operable fronthaul evolution
- Review activities across all relevant Standard Development Organizations (SDOs) to identify gaps where further work may be needed.
- Propose a way forward within these SDOs.

Relation with COMBO: The content of this white paper is fed by COMBO results and COMBO partners from Orange and DTAG

Contributions from COMBO: COMBO delivered contributions to the view on Fronthaul usage and potential limitations with respect to 5G thus motivating an alternative view on this topic and stimulating a discussion in several standardization bodies about the right approach.

JOCN 2-part paper on NG-PON2

Contribution topic	SDO	SDO Framework	SDO Reference	Timeline	Status	Action	COMBO technical area
JOCN 2-part paper on NG-PON2	FSAN/ITU-T Q2/SG15	G.989.2 / NG-PON2	G.989.2	2015 Q1 - 2015 Q4	in progress	Contributing	Optical Access Network design for FMC

Abstract: FSAN, with contributions from COMBO project, was invited by JOCN journal to write a 2-part paper on technical insight and development rationales of the 40-Gigabit-capable Passive Optical Networks (NG-PON2). The physical layer specification of 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. The first part of the paper focuses on optical link design topics, whereas the second part focuses on the design considerations of spectral excursion, as well as management, control, and technical feasibility of such multi-wavelength PON system.

Relation with COMBO: There are several aspects where influence between FSAN/Q.2/G.989 and the COMBO project have happened. It also holds for older projects like EU FP7 OASE, since FSAN work on NG-PON2 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.

Contributions from COMBO: "Influence from COMBO onto G.989 includes NG-PON2 support of fronthaul bit rates and the allowance of a dedicated expanded-spectrum PtP WDM PON variant. 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).

COMBO also was influenced by FSAN work, through e.g. 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 refers to the G.989 AMCC, which is the transparent signaling 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, include reach extenders, higher bit rates of the PtP WDM sub-system, OAM (monitoring) and also some further work on hybrid and WR-ODN and the related coexistence aspects.

The 2-part JOCN paper on NG-PON2 should be published before end of 2015.

4.2 Standardization activities following the bottom up approach

As shown in the table below , the bottom up approach activities were focused on monitoring mainly 3GPP but also Wi-Fi Alliance and others for contribution opportunities. Despite our efforts for the time being no such an opportunity has been identified.

Contribution topic	SDO	SDO Framework	SDO Reference	Timeline	Status	Action
Enhancements to WEBRTC interoperability (not for slides)	3GPP	SA1: Feature or Study Item		2014	closed	Monitoring
Study on Application specific Congestion control for Data Communication (not for slides)	3GPP	SA1: Feature or Study Item		2014	closed	Monitoring
Study on enhancements for Infrastructure based data Communication Between Devices	3GPP	SA1: Feature or Study Item		2014 - 2016	in progress	Monitoring
Study on need for Multiple Access Point Names	3GPP	SA1: Feature or Study Item		2014 - 2016	in progress	Monitoring
Study on Co-ordinated packet data network gateway (P-GW) change for SIPTO	3GPP	SA1: Feature or Study Item		2014 - 2016	in progress	Monitoring
Study on Flexible Mobile Service Steering	3GPP	SA1: Feature or Study Item		2014 - 2016	in progress	Monitoring
Study on RAN Sharing Enhancements on GERAN and UTRAN	3GPP	SA2: Feature or Study Item		2014 - 2016	in progress	Monitoring
Network-Based IP Flow Mobility	3GPP	Network-Based IP Flow Mobility (NBIFOM)		2014 H2 - 2015 H1	in progress	Monitoring
"Nodal Requirements for Converged Policy Management"	BBF	WT-300	WT-300	… - 2014 H2	closed	Contribute
Nodal requirements for interworking between next generation fixed and 3GPP wireless access	BBF	TR - 291	TR - 291	… - 2014 H1	closed	Contribute
Access Point or Devices features realted to WiFI, or entities like HS2.0, Remediation server, policy server, etc.	WiFi Alliance			2014 - 2016	in progress	Monitoring
The only documents that can be considered as specifications are the WRIX that regulate roaming between Wi-Fi operators.	WBA (Wireless Broadband Alliance)			2014 - 2016	in progress	Monitoring
Radio Over Ethernet Encapsulations and Mappings	IEEE 1904.3 Task Force Standard			2015-	in progress	Monitoring
tight Wi-Fi/LTE integration hybrid LTE/DSL access interface selection Wi-Fi/LTE handover	3GPP	CT1, CT3		2015	in progress	Monitoring

5 Conclusion

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

Consortium has experienced high demand towards the integrated view on FMC aspects from the number of stakeholders. The number of invited papers and talks (11 conference papers, 3 journal papers, 3 keynotes, 12 workshop presentations including FSAN workshop) 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 producing a number of educational materials and comprehensive FMC tutorial.

Being at the end of 2nd period, COMBO is standing in front of implementation of its findings into demonstration setups, and thus it shall also influence project dissemination activities during the last period. Consequently, Consortium anticipates appearance of publications, presentations – as well as face-to-face meetings with interested stakeholders, which would contain testing and verification results during 3rd period.

Furthermore, functional and structural convergence, specified and described in COMBO will also influence the dissemination policy during the 3rd period. More particularly, at least 2 journal articles – one on structural another on functional convergence are planned for submission during 3rd period.

Some standardization activities that have been accomplished so far imprinted the fix mobile convergence vision developed in the project on standard organizations such as BBF and FSAN.

Others standard related activities, mostly the Universal Access Gateway white paper, are currently fulfilling the role of preparing the framework for the future standardization of convergent nodes in the networks.

6 References

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

[2] COMBO Deliverable D3.3 - Analysis of transport network architectures for structural convergence

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