H2020 5G PPP 5G-Crosshaul project
Grant No. 671598

D6.3: Year 3 achievements and future plan

Abstract

This deliverable (D6.3) reports on all the communication and dissemination activities undertaken in Year 3 from 1st of July 2017 to 31st of December 2017. In addition, as the final deliverable from WP6, it also provides a summary of the key achievements throughout the project lifetime and outlines the prospects of future activities after the end of the project.

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List of Acronyms

Acronym	Description
3GPP	Third Generation Partnership Project
5G PPP	5G Public Private Partnership
API	Application Program Interface
BBF	Broadband Forum
BBU	Baseband Unit
BoF	Birds of a Feather (IETF Pre-Working Group efforts)
BPON	Broadband Passive Optical Network
BSS	Base Station Subsystem
CDN	Content Delivery Network
CNF	Conference dissemination
CP	Cyclic Prefix
CPRI	Common Public Radio Interface
CSA	Coordination and support Action
CU	Centralized Unit
DetNet	Deterministic Networking (IETF)
DL	Downlink
DU	Distributed Unit
eCPRI	Enhanced CPRI
eMBB	Enhanced Mobile Broadband
EPC	Evolved Packet Core
ETP	European Technology Platform
ETSI	European Telecommunications Standards Institute
FFT	Fast Fourier Transform
FSAN	Full Service Access Network
GSM	GSM Association
GPON	Gbit/s-capable PON
HetNet	Heterogeneous Networks
ICT	Information and Communication Technology
IEEE	Institute of Electronics and Electrical Engineering
IETF	Internet Engineering Task Force
iFFT	Inverse Fast Fourier Transform
IMT	International Mobile Telecommunications
IoT	Internet of Things
IP	Internet Protocol
IPR	Intellectual Property Rights
IRTF	Internet Research Task Force
ISG	Industry Specification Group (ETSI)
IT	Information Technology
ITU-R	International Telecommunications Union – Radiocommunication sector

ITU-T	International Telecommunications Union – Telecommunications standardization sector
JRN	Journal dissemination
LAN	Local Area Network
LTE / -A	Long Term Evolution / -Advanced (3GPP)
MAC	Medium Access Control
MAG	Magazine dissemination
MEC	Mobile Edge Computing
mMTC	Massive Machine Type Communications
MPLS	Multiprotocol Label Switching
MWC	Mobile World Congress
mWT	Millimetre Wave Transmission (ETSI)
NFV	Network Functions Virtualization
NFVRG	NFV Research Group (IRTF)
NGFI	Next Generation Fronthaul Interface
NGMN	Next Generation Mobile Networks
NG-PON	Next Generation Passive Optical Network
OAM	Operation, Administration and Maintenance
ODL	OpenDayLight
OF	Open-Flow (ONF)
ONF	Open Networking Foundation
ONT	Optical Network Terminal
OTN	Optical Transport Network
OSS	Operations Support System
PAR	Project Authorization Request
PDCP	Packet Data Convergence Protocol
PHY	Physical Layer
PoC	Proof of Concept
PON	Passive Optical Network
PRACH	Physical Random Access Channel
QoS	Quality of Service
R&D	Research and Development
RAN	Radio Access Network
RE	Radio Equipment
RLC	Radio Link Control
RNC	Radio Network Controller
RoE	Radio Over Ethernet
RoF	Radio Over Fibre
RRC	Radio Resource Control
RRH	Remote Radio Head
RRU	Remote Radio Unit
SCF	Small Cells Forum
SDN	Software Defined Networks
SDNRG	SDN Research Group (IRTF)
SDO	Standard Development Organization

SLA	Service Level Agreement
TCO	Total Cost of Ownership
TDM	Time Division Multiplexing
THES	Thesis dissemination
TTA	Telecommunications Technology Association
TSN	Time Sensitive Networking
UL	Uplink
URLLC	Ultra-Reliable Low-Latency Communications
VIM	Virtual Infrastructure Manager
VNF	Virtual Network Function
WDM	Wave Division Multiplexing
WG	Working Group
XCI	Xhaul Control Infrastructure
XGPON	10Gbit/s-capable PON

Executive Summary

This deliverable D6.3 concludes the reporting of the communication and dissemination activities carried out throughout 5G-Crosshaul project lifetime. It reports on the achievements in the Year 3 from 01 July 2017 to 31 December 2017 and summarizes all cumulative achievements throughout the project lifetime. It also provides an outline of future activities that may be carried after the project end on 31 December 2017. Some highlights on the key achievements in Year 3 include:

- Publication of additional 17 peer-reviewed articles (11 proceedings and 6 journals and magazines).
- Delivering of 10 further talks and a final workshop organized at WWRF.
- Publication of the eCPRI specification including standard contributions from key partners in 5G-Crosshaul.

Cumulatively over the project lifetime from 01 July 2015 to 31 December 2017, the project exceeded on all metrics set for the targeted activities as highlighted below:

- Over 35 normative contributions feeding into key standardization specifications such as: eCPRI, G.metro, IETF CCAMP, IETF DETNET, and ONF. This is in addition to some 25 (informative) dissemination activities in standardization bodies and forums such as NGMN, ITU-T, FSAN, ETSI, IEEE, BBF, ONF.
- Nearly 100 peer-reviewed publications in IEEE and ACM proceedings, journals and magazines, over 75 talks and panels delivered at key events, and nearly 15 workshops and special sessions (co-) organized.
- Over 25 demonstrations exhibited at various events including at the flagship Mobile World Congress both in 2016 and 2017 and at the EC conference EuCNC in 2016 and 2017.
- Some 5 patent applications developed and reported by the project consortium.
- Proactive communication through blogs, press releases, video interviews, and leaflets, all actively promoted through various channels.

Some follow-up activities after the end of the project in December 2017 are also planned including a continuous contribution of the project results into ongoing and forthcoming research projects and standardization activities. This is in addition to a final press release and a final leaflet for distribution at MWC 2018.

1 Introduction

This deliverable D6.3 concludes the reporting of the communication and dissemination activities carried out throughout 5G-Crosshaul project lifetime. It reports on the achievements in the Year 3 from 01 July 2017 to 31 December 2017 and summarizes all cumulative achievements throughout the project lifetime. It also provides an outline of future activities that may be carried after the project end on 31 December 2017.

This deliverable is organized in four chapters corresponding to different types of activities, namely, (1) communication and public activities, (2) dissemination and collaboration activities, (3) standardization activities, and (4) exploitation activities.

Chapter 2 reports on the communication and public activities undertaken in Year 3, along with a summary of the achievements throughout the project duration.

Chapter 3 reports on the dissemination activities including talks, workshops, and peer-reviewed scientific articles, as well as collaboration activities undertaken in the framework of the 5G-PPP. This is both in Year 3 and throughout the project lifetime.

Chapter 4 focuses on standardization activities in Year 3 and all along the project execution. A special overview is given here for the eCPRI specification, which is a key standard of new fronthaul interface released in August 2017 including contributions from three partners in 5G-Crosshaul consortium.

Chapter 5 summarises the key innovations that have been identified in different technological aspects of the project. It also reports on 5G-Crosshaul-related commercial products and patents that have been developed by the partners.

The document ends with conclusions summarizing the achievements over the project lifetime from 01 July 2015 to 31 December 2017, and outlines the prospects of future activities after the project end.

2 Communication and Public Activities

This chapter reports all the communication activities undertaken in Year 3 from 01 July 2017 to 31 December 2017. It also presents a summary of achievements throughout the execution phase of the project and an outline of any activity which will continue after the project end.

2.1 Year 3 Achievements

The communication activities in Year 3 included:

- Publishing 6 video interviews taken during 5G-Crosshaul project exhibition at the EuCNC 2017 conference. These are summarized in Table 1.
- Publishing a blog article relating to a final demonstration by Ericsson "Viability tests of Ericsson's pre-commercial 5G technology" at 5TONIC, 22 Sep. 2017, https://www.5tonic.org/news/ericsson-demos-5tonic-technology-developed-within-5g-crosshaul-project
- Planning for a final press release and a final leaflet for distribution at the upcoming MWC 2018 flagship event.

Table 1: Video interviews given in Year 3.

#	Month	Description	Lead partners
1	Sep'17	Interview on the project demonstrations at the EuCNC 2017: Demo 1: SDN-based TV Broadcasting Service https://youtu.be/s7TSL5g6480	VISIONA
2	Sep'17	Interview on the project demonstrations at the EuCNC 2017: Demo 2: Energy Monitoring and Management for Network Paths https://youtu.be/35TB9dHCagA	NXW, NOKIA, POLITO
3	Sep'17	Interview on the project demonstrations at the EuCNC 2017: Demo 3: Resource management of the 5G-Crosshaul https://youtu.be/QJs7lNB9OG0	CTTC, NEC
4	Sep'17	Interview on the project demonstrations at the EuCNC 2017: Demo 4: Next Generation fronthaul/backhaul over hybrid Optical Wireless and mmWave Link https://youtu.be/pCvwelbqELY	HHI
5	Oct'17	Video interview provided by Project Coordinator to 5G Public Private Partnership (5G PPP), 2017: https://www.youtube.com/watch?v=78wiM3KH210	UC3M
6	Oct'17	Video interview provided by SME to 5G Public Private Partnership (5G PPP), 2017: https://www.youtube.com/watch?v=gZ-UNflObdA	VISIONA

2.2 Summary of Achievements Over Entire Project Duration

Table 2 summarises 5G-Crosshaul achievements relating to all communication and public activities undertaken during the project lifetime.

Table 2: Summary of communication activities throughout the project lifetime.

Targeted Goal	**Highlights of Corresponding Achievement**
Deployment of the project portal for an up-to-date communication on all events and milestones from the project to the wide community, as well as social networks accounts to complement with the project portal.	The project portal was released in July 2015: www.5g-crosshaul.eu Throughout the execution phase of the project, the project portal has been continuously updated with new contents on talks, workshops, demonstrations, and events undertaken and planned. A free access to download public presentations and materials from the partners was also given, subject to partner permission. Figure 1 shows that, in the first three quarters of 2017, the project portal has attracted at least 3,000 visitors every month (~100 people per day on average), reflecting on a considerable attention globally. In addition, both a twitter account (@xhaul_eu) and a LinkedIn group (5G Crosshaul) have been established at the same time. Throughout the project execution, there have been 86 Tweets and 48 posts in the Twitter Page and LinkedIn Group respectively.
Delivery of video/audio for promoting the project vision, concept and initial results.	During the project execution phase, over 15 video/audio interviews have been delivered including over 10 interviews relating to demonstrations exhibited at MWC flagship evens and the EuCNC conference. A YouTube Channel for 5G-Crosshaul was established in November 2015 to collect videos and interviews relating to the project. So far over 20 videos have been uploaded to this YouTube Channel.
Delivery of social media/blog articles for promoting the project vision, concept and initial results.	Overall 5 blog articles relating to 5G-Crosshaul concept and results have been posted by the partners in well-known and popular online magazines such as: • RCR Wireless (https://www.rcrwireless.com/) • NetworkWorld.com (https://www.networkworld.com/)
Press release and leaflets for promoting the project	Several press releases have been delivered starting with the announcement of the project kick off, and focusing next on the exhibitions at MWC flagship event, and finally on pre-commercial technology trials. Two leaflets have also been designed and distributed at MWC'16 and MWC'17, and a final leaflet is under preparation aiming at MWC'18.

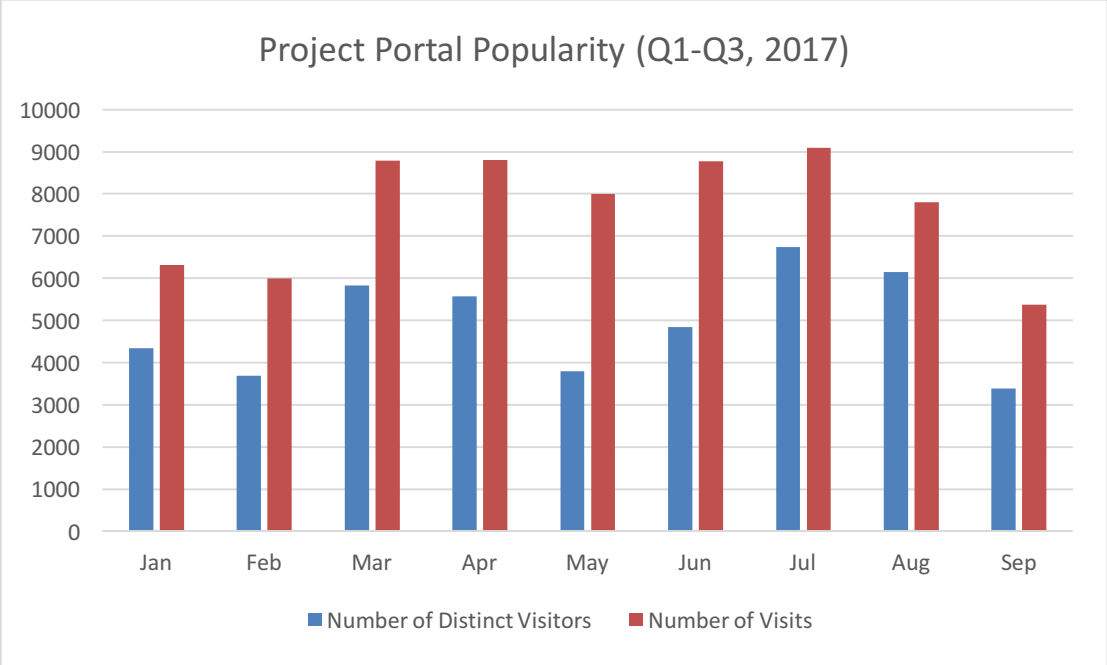

Figure 1: Statistics on the number of visits to the 5G-Crosshaul portal.

Figure 2 gives an overview of the communication plan as executed in the 5G-Crosshaul project. This reflects on a successful execution throughout the project and this is across diverse communication activities.

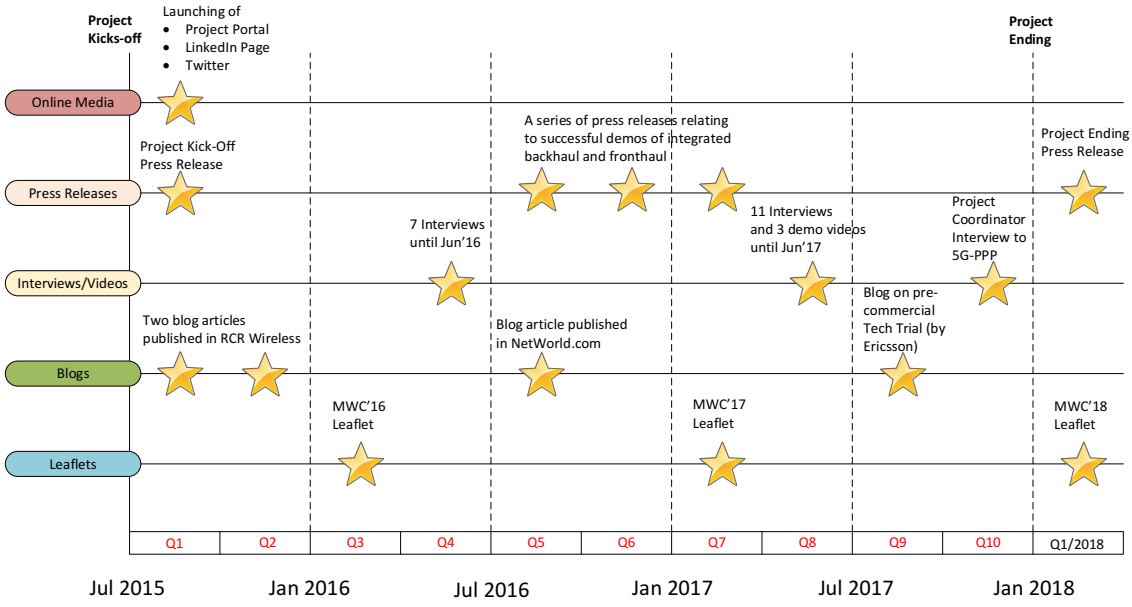

Figure 2: Overview of the communication plan as executed during the project.

2.3 Outline of Activities Planned After Project End

The following communication activities are planned after the project ends on 31 December 2017:

- Press release announcing the completion of the project and its key innovations.
- Final leaflet summarizing the key achievements of the project. The leaflet will be distributed by partners present at MWC 2018 event.
- Continuous communication through the project portal, the social networks, and the 5G-PPP communication and dissemination working group.

3 Dissemination and Collaboration Activities

This section gives an update of the dissemination and collaboration activities during Year 3, as well as a summary of achievements throughout the project. It also outlines activities that may occur after the project end.

3.1 Activities Update for Year 3

3.1.1 Scientific Publications

The journal and conference publications of 5G-Crosshaul during Year 3 are listed in the Table 3 and Table 4 respectively. In total, 3 journals, 1 magazine and 11 conference proceedings papers have been published and an additional 3 journal and 1 conference papers submitted for publication in 2018.

Table 3: Journal/Magazine Papers Publications in Year 3.

#	Type	Month	Description	Leading Partner
1	JRN	Aug'17	Distributed Downlink Power Control for Dense Networks with Carrier Aggregation, by Z. Limani Fazliu, C. F. Chiasserini, G. M. Dell'Aera and E. Hamiti, *IEEE Transactions on Wireless Communications*	POLITO
2	MAG	Sep'17	Advertisement Delivery and Display in Vehicular Networks: Using V2V Communications for Targeted Ads, by C. F. Chiasserini, F. Malandrino and M. Sereno, *IEEE Vehicular Technology Magazine*, vol. 12, no. 3, pp. 65-72.	POLITO
3	JRN	Sep'17	Cellular Network Traces Towards 5G: Usage, Analysis and Generation, by F. Malandrino, C. F. Chiasserini and S. Kirkpatrick, *IEEE Transactions on Mobile Computing*	POLITO
4	JRN	Oct'17	Area formation and content assignment for LTE broadcasting, by C. Casetti, C. F. Chiasserini, F. Malandrino, C. Borgiattino, *Computer Networks, Vol. 126, 2017, pp. 174-186.*	POLITO
5	JRN	Dec'17	"Experimental Validation of a Converged Metro Architecture for Transparent Mobile Front-/Back-Haul Traffic Delivery using SDN-enabled Sliceable Bitrate Variable Transceivers" by J. M. Fabrega, M. Svaluto Moreolo, L. Nadal, F. J. Vílchez, R. Casellas, R. Vilalta, R. Martínez, R. Muñoz, J. P. Fernández-Palacios, L. M. Contreras, Submitted as invited paper to *IEEE/OSA Journal of Lightwave Technology*	CTTC TID
6	JRN	Dec'17	Unleashing 5G-Crosshaul network to orchestrate end-to-end network services in a multi-domain multi-technology transport network, by J.Baranda, J. Mangues-Bafalluy, J. Núñez, J. L. de la Cruz, R. Casellas, J.X. Salvat, C. Turyagyenda, submitted to	CTTC NEC IDCC

			IEEE Communications Magazine - Network and Service Management Series.	
7	JRN	Dec'17	Improved LPC-Based Fronthaul Compression with High Rate Adaptation Resolution, by Leonardo Ramalho, Igor Freire, Chenguang Lu, Miguel Berg and Aldebaro Klautau, submitted to *IEEE Communications Letters*.	EAB

Table 4: Conference Papers Publications in Year 3.

#	Month	Description	Leading Partner
1	May'17	Traffic adaptive formation of mmWave meshed backhaul networks, by H. Ogawa, G. K. Tran, K. Sakaguchi, and T. Haustein (IEEE Conf. on Communications ICC Workshop)	HHI
2	Jul'17	Energy Consumption Measurements in Docker, by S. S. Tadesse, F. Malandrino and C. F. Chiasserini (*IEEE 41st Annual Computer Software and Applications Conference (COMPSAC), Turin, pp. 272-273*)	POLITO
3	Jul'17	Control Plane Architectures Enabling Transport Network Adaptive and Autonomic Operation by R. Casellas, R. Vilalta, A. Mayoral, R. Martínez, R. Muñoz and L.M. Contreras (International Conference on Transparent Optical Networks, ICTON 2017)	CTTC, TID
4	Jul'17	Mobile Front-/Back-Haul Delivery in Elastic Metro/Access Networks with Sliceable Transceivers based on OFDM Transmission and Direct Detection, by J. M. Fabrega, M. Svaluto Moreolo, L. Nadal, F.J. Vílchez, J.P. Fernández-Palacios and L.M. Contreras (International Conference on Transparent Optical Networks, ICTON 2017)	CTTC, TID
5	Aug'17	Characterizing Docker Overhead in Mobile Edge Computing Scenarios, by G. Avino, M. Malinverno, F. Malandrino, C. Casetti, and C. F. Chiasserini, (ACM SIGCOMM HotConNet Workshop, Los Angeles, CA, USA)	POLITO
6	Sep'17	Experimental Validation of a Converged Metro Architecture for Transparent Mobile Front-/Back-Haul Traffic Delivery using SDN-enabled Sliceable Bitrate Variable Transceivers, by J. M. Fabrega, M. Svaluto Moreolo, L. Nadal, F. J. Vílchez, R. Casellas, R. Vilalta, R. Martínez, R. Muñoz, J. P. Fernández-Palacios, L. M. Contreras (European Conference on Optical Communications, ECOC 2017)	CTTC, TID
7	Sep'17	Delay Analysis of Fronthaul Traffic in 5G Transport Networks, by G. O. Perez, J. A. Hernandez, and D. L. Lopez (IEEE International Conference on Ubiquitous Wireless Broadband ICUWB'2017)	UC3M
8	Sep'17	Transport Network Design for FrontHaul, by P. Sehier, A. Bouillard, F. Matthieu, T. Deiß (3rd IEEE Workshop on	NOK-N

		Next Generation Backhaul/Fronthaul Networks - BackNets 2017)	
9	Nov'17	Quality Probe for Testing Multimedia Content in 5G Networks, by J.P. López, D. Jiménez, C. Navarro, J.A. Rodrigo, J.M. Menéndez, and N. Sánchez (NEM Summit 2017)	VISIONA
10	Nov'17	Hybrid SDN: Evaluation of the impact of an unreliable control channel, by M. Osman, J. Nunez-Martınez and J. Mangues-Bafalluy (IEEE NFV-SDN'17 NFVPN Workshop)	CTTC
11	Nov'17	Resource Management in a Hierarchically Controlled Multi-domain Wireless/Optical Integrated Fronthaul and Backhaul Network, by J. Baranda, J. Nunez-Martınez, Inaki Pascual, J. Mangues-Bafalluy, A. Mayoral, R. Casellas, R. Vilalta, R. Martınez, R. Munoz, J. X. Salvat, A. Garcia-Saavedra, X. Li, J. Kocur (IEEE NFV-SDN conference, Demo Paper)	CTTC NEC CND
12	Dec'17	DCT-Based Compression Scheme for OFDM Baseband Signals, by Maria Nilma Fonseca, Leonardo Ramalho, Aldebaro Klautau, Chenguang Lu, Miguel Berg, Stefan Höst (Submitted to Wireless Days 2018)	EAB ULUND
13	Dec'17	FluidRAN: Optimal vRAN/MEC Orchestration, by A. Garcia-Saavedra, X. Costa-Perez, D. Leith, G. Iosifidis (Accepted by IEEE INFOCOM 2018)	NEC

3.1.2 Talks/Panels/Webinars/Whitepapers

Table 5 lists all presentation activities delivered including talks, panels and webinars. As reported, 11 activities are delivered during this period. This is worth noting that some of the presentations are delivered in a special session organized by 5G-Crosshaul within the 39th WWRF Meeting. Also, the footprint of 5G-Crosshaul has again extended to Asia by a presentation delivered at the Taipei 5G Summit in Taiwan.

Table 5: Talks and panels delivered in Year 3.

#	Month	Description	Leading Partner
1	Jul'17	"Sharing of Crosshaul Networks via a Multi-Domain Exchange Environment for 5G Services", by Luis M. Contreras, Carlos J. Bernardos, Antonio de la Oliva, Xavier Costa-Pérez at IEEE NetSoft 2017, Bologna, Italy.	UC3M
2	Jul'17	"5G-Crosshaul Project overview and Demo Activity", by C. F. Chiasserini at IEEE 5G Summit, Thessaloniki, Greece.	POLITO
3	Sep'17	"EU Project 5G-Crosshaul - 5G Transport Systems", by A. Mourad and C. Turyagyenda at European Conference on Optical Communication (ECOC 2017), Gothenburg, Sweden.	IDCC
4	Sep'17	"5G-Crosshaul Architecture Implementation", by A. Azcorra, at The 4th Taipei 5G Summit, Taipei, Taiwan.	UC3M
5	Sep'17	"Towards 5G Mobile Transport Platforms for Industry Verticals", by A. Bouillard and X. Costa-Pérez, at 3rd IEEE	NOK-N, NEC

		Workshop on Next Generation Backhaul/Fronthaul Networks - BackNets 2017, Toronto, Canada.	
6	Oct'17	"Data-plane Integration for 5G Fronthaul and Backhaul – A proof-of-concept from 5G-Crosshaul", by C. Turyagyenda, at Special Session of WWRF 39th Meeting - 5G Mobile Transport Networks, Barcelona, Spain.	IDCC
7	Oct'17	"Multi-Domain Hierarchical 5G-Crosshaul Control Infrastructure", by J. Mangues-Bafalluyz, at Special Session of WWRF 39th Meeting - 5G Mobile Transport Networks, Barcelona, Spain.	CTTC
8	Oct'17	"Energy Efficient Services Orchestration in Converged Fronthaul/Backhaul", by G. Carrozzo, at Special Session of WWRF 39th Meeting - 5G Mobile Transport Networks, Barcelona, Spain.	NXW
9	Oct'17	"Slicing Across Multiple Administrative Domains", by L. M. Contreras, at Special Session of WWRF 39th Meeting - 5G Mobile Transport Networks, Barcelona, Spain.	TID
10	Oct'17	"Cellular Access Multi-Tenancy through Small-Cell Virtualization and Common RF Front-End Sharing", by J. Mendes, X. Jiao, A. Garcia-Saavedra, F. Huici, I. Moerman at ACM WiNTECH 2017 Workshop, Snowbird, Utah, USA.	NEC
11	Dec'17	5G-PPP Architecture Working Group White paper V2.0	NEC, IDCC, UC3M

3.1.3 Workshops

During Year 3, it is worth highlighting that the consortium partners CTTC and IDCC have organized a special session in the 39th meeting of WWRF, entitled **5G Mobile Transport Networks**. The special session covers not only talks from 5G-Crosshaul consortium, but also presentations from the 5G PPP Phase-1 projects 5G-XHaul and 5G-EX and Phase-2 Project 5G-Transformer.

VISIONA has also organized at Technical University of Madrid a training session entitled 5G for "dummies" in Media Sector targeting junior and senior researchers highly interested in the potential that 5G network capabilities has for developing innovative media-related applications. The seminar counted on with researchers from 5G PPP Phase-2 Project of 5G-MEDIA which deals with programmable edge-to-cloud virtualization for the 5G media industry.

Table 6: Workshops organized.

#	Month	Workshop	Country
1	Oct'17	5G Mobile Transport Networks (Special Session of WWRF 39th Meeting): https://5g-ppp.eu/5g-crosshaul-final-workshop-wwrf39/	Spain
2	Dec'17	5G for "dummies" in Media Sector seminar (Technical University of Madrid)	Spain

3.1.4 Demonstrations

In Year 3, 5G-Crosshaul focused most of the efforts on delivering several integrated demonstrations at the 5G-Crosshaul testbed sites in Madrid, Barcelona, Berlin and Taiwan. Professional videos were taken and will be released before the project final review due in March 2018. Table 7 below reports two additional demonstration activities exhibited at conferences or workshops.

Table 7: Demonstrations exhibited at conferences or workshops.

#	Month	Description	Leading Partners
1	Oct'17	Resource management of the 5G-Crosshaul network at WWRF 39th Meeting	CTTC
2	Nov'17	Resource Management in a Hierarchically Controlled Multi-domain Wireless/Optical Integrated Fronthaul and Backhaul Network at IEEE NFV-SDN'17 NFVPN Workshop	CTTC NEC CND

3.1.5 5G-PPP Collaborations

In Year 3, 5G-Crosshaul has continued its collaboration within the 5G-PPP, through joint work with 5G-PPP projects and participation in the 5G-PPP working groups. In this period, the following activities are particularly worth noting:

- IDCC continue to contribute to **5G-PPP Pre-Standard Working Group** list of relevant SDO working groups and standard contributions from 5G-Crosshaul. IDCC also led the efforts on 5G-Crosshaul standardization impact in the 5G-PPP architecture working group white paper. IDCC has also led a bid to the open call by 5G-PPP Steering Board for exhibition at MWC'18.
- NOK-N has collaborated with **5G-PPP Software Network Working Group** to release a white paper entitled "*Vision on Software Networks and 5G*", which defines terminology and identifies architectural trends and existing gaps in combinations of NFV and SDN, as well as relevant standardization bodies and open source initiatives. Furthermore, reusable assets from 5G-Crosshaul has been provided to the working group for evaluation in 5G-PPP Phase-2 projects.
- POLITO has collaborated with **5G-PPP NETMGMT Working Group** to release a white paper entitled "*5G-PPP Cognitive Network Management for 5G*", which is published in Mar'17.
- NEC has collaborated with **5G-PPP Architecture Working Group** to revise the white paper entitled "*View on 5G Architecture (Version 2.0)"* for public consultation in Jul'2017. This revised white paper highlights the key design recommendations identified by the Phase 1 projects toward the 5G architecture

design and provides a baseline architecture to be facilitated by the new Phase 2 projects to assist further development.

- TI has collaborated with **5G-PPP Vision Working Group** to identify new technical areas, business models, and vision of mobile network after 5G Phase 2. Also, some topics of 5G-Crosshaul activities may be utilized by the WG to identify the deployment scenarios for verticals.
- VISIONA continue to follow **5G-PPP Trials WG** to participate the work on Phase 3 pre-structuring model, as well as other activities of the Trials WG.
- VISIONA continue to follow **5G-PPP SME WG** to increase the visibility of SMEs, for the purposes of identifying new collaboration opportunities within 5G-PPP.

In addition to the above activities specific to the 5G-PPP working groups, the following activities have also been undertaken towards the 5G-PPP or across projects within the 5G-PPP:

- IDCC has provided an article on 5G-Crosshaul to **European 5G Annual Journal 2017**, which is published in Sep'17 by 5G-PPP. (https://5g-ppp.eu/annual-journal/)
- The consortium partners co-organized a special session at the 39th meeting of WWRF, and invited talks from 5G PPP Phase-2 Project of 5G-Transformer. 5G-PPP has released a news release relating to the workshop organized by 5G-Crosshaul at the 39th meeting of WWRF (https://5g-ppp.eu/5g-crosshaul-final-workshop-wwrf39/).
- CTTC has carried out a collaboration with H2020 Metrohaul project. The results obtained were presented in the paper R. Casellas, R. Vilalta, A. Mayoral, R. Martínez, R. Muñoz, L. Miguel Contreras, "Control Plane Architectures Enabling Transport Network Adaptive and Autonomic Operation," in Proceeding of International Conference on Transparent Optical Networks (ICTON2017), 2-6 July, 2017, Girona (Spain).
- During the 10th NEM Summit 2017 organized 29-30 December, 2017, in Madrid (Spain), VISIONA partners had the opportunity to meet 5G-PPP 5G-MEDIA partners and share experiences in 5G-Crosshaul regarding the TV Broadcasting application in particular, and how 5G network architectures, technologies and infrastructures can be exploited for developing innovative media-related applications.
- VIS and NXW expertise was also given visibility during the presentation on SMEs made by the European Technology Platform for communications networks and services Networld2020 on 9 November at the ICT Proposer's Day-5GPPP-Phase 3 & Global 5G Collaborations in Budapest.

3.2 Analysis of Achievements Over Entire Project Duration

Table 8 provides the records of scientific publications, talks/panels, demonstrations, and organized/sponsored workshops throughout the whole execution phase. The record is shown for each period (Year 1, Year 2, and Year 3) and compared to the target number set in each period. It is crystal clear from Table 8 that the project exceeded by far its targets set in each category of dissemination activities. Over 90 peer-reviewed publications have been published, 75 talks delivered, 14 workshops co-organized, and 25 demonstrations at conferences and showcases.

Table 8: Summary of dissemination achievements throughout the project.

	Year			Total
	Year 1: Jul'15-Jun'16	Year 2: Jul'16-Jun'17	Year 3: Jul'17-Dec'17	
Scientific Publications (Achievement/Target)	33/20	46/20	13/10	92/50
Talks/Panels/Webinar (Achievement/Target)	37/10	28/20	10/5	75/35
Workshops (Achievement/Target)	7/1	5/2	2/1	14/4
Demonstrations (Achievement/Target)	12/2	11/2	2/2	25/6

- The total number of peer-reviewed scientific publications has reached 91, which is almost double of the targeted number. By considering the publication list more closely, the consortium has published 26 journal/magazine papers and 66 conference papers in the last two and half years. Such a result has verified the novelty of the ideas rooted in this consortium. Almost 75% of the publications are presented at conferences, while the rest targeted journals or magazines.
- The consortium has delivered 75 presentations/panels and organized/sponsored 14 workshops over the entire project execution phase. This is worth noting that in MWC'17 alone, three panel activities have been conducted, including a dedicated panel moderated by IDCC entitled "Crosshaul – The fusion of Fronthaul and

Backhaul in 5G". Moreover, 81% of the activities are based on talks delivered in various events held in Europe as well as other regions of the world, such as North America and Asia. This shows that the consortium has successfully shared its impactful innovations and visions globally.

- For demonstrations, the consortium has showcased its technologies via real-world platforms 25 times at key events throughout the project execution. This includes 7 demonstrations at MWC'16 and MWC'17, 5 at EUCNC'16 and EUCNC'17, 4 at 5G-Global 2017, 2 at ONF plug fests, and the rest at various conferences and workshops.

3.3 Outline of Activities Planned After Project End

Further dissemination and collaboration activities are anticipated after the project end. These include:

- Additional scientific publications in reputed (e.g. IEEE and ACM) journals and conference proceedings.
- Additional exhibition of demonstrations noticeably integrated demonstrations finalized in Q4'17.
- Continuous collaboration with 5G-PPP projects and working groups to reflect 5G-Crosshaul results into the 5G-PPP programme.

4 Standardization Activities

This chapter provides first an overview of the new eCPRI standard completed and released in August 2017 including key contributions from 5G-Crosshaul consortium partners. A summary of standardization achievements throughout the project lifetime is then provided along with an outline of potential future activities.

4.1 New Fronthaul Interface Standard - eCPRI

4.1.1 Introduction to eCPRI

The goal of eCPRI is to introduce a new fronthaul interface that can satisfy the requirement of high bandwidth 5G use cases, where higher link efficiency is needed in order to handle tremendous volume of data that will be transported over the fronthaul. In particular, eCPRI targets at the functional split within PHY layer (i.e. Option 7 defined by 3GPP), which allows better coordination among multiple geographical separated radio units. Thus, eCRPI is able to comply with the requirements of more stringent radio technologies features, including timing and frequency accuracy, as well as bandwidth capacity. In general, eCRPI is a packet based fronthaul interface between a CU and a DU (these two entities are dubbed as eREC and eRE in eCPRI specifications respectively), with the same level of interoperability as CPRI. A high-level overview of eCPRI transport is shown in Figure 3:

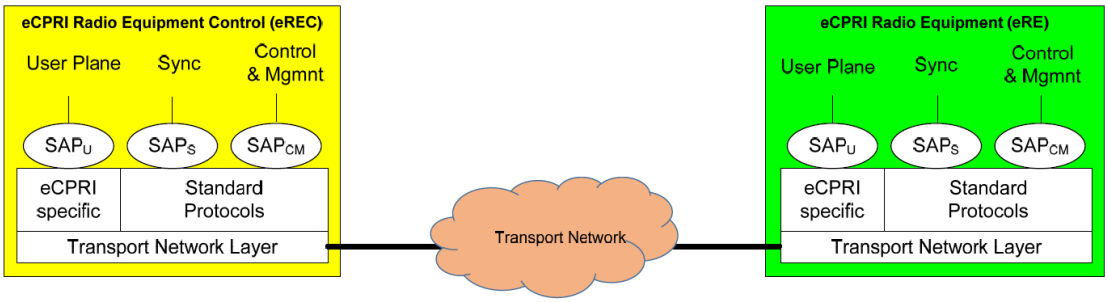

Figure 3: Overview of eCPRI transport.

Basically, eCPRI is applicable to all functional split options, with scalable bandwidth in accordance to the user plane traffic. As aforementioned, it was mainly designed for functional splits at PHY level. A set of PHY-level functional splits supportable by eCPRI are illustrated in Figure 2. These examples include two available split options for downlink with intra-PHY split, namely I_D and II_D. For uplink, there is one intra-PHY split option I_U. The estimated bandwidth for user data under these split options are 4, 20, and 20 Gbps for I_D, II_D and I_U respectively. The detailed assumptions for these estimations can be found in D2.2.

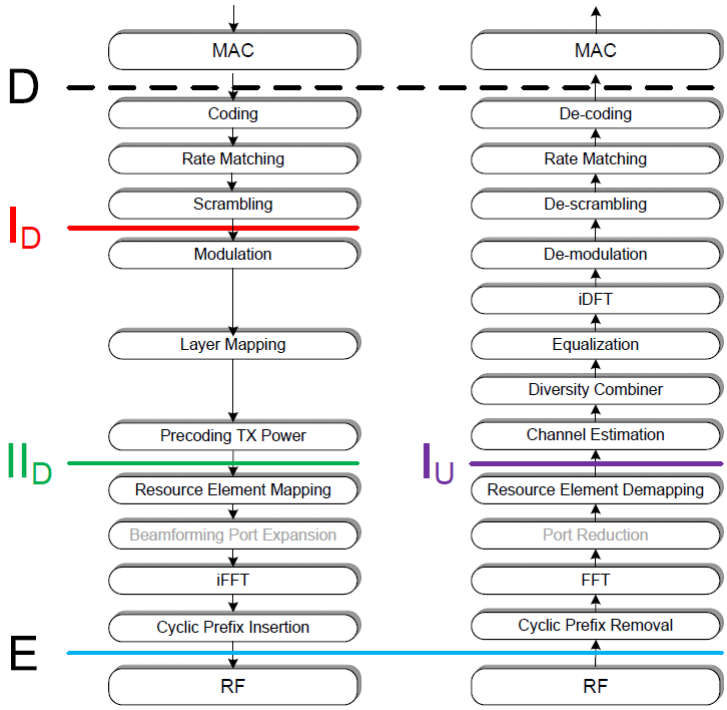

Figure 4: eCPRI split options.

4.1.2 Specifications of eCPRI

The user plane message for eCPRI comprises a 4-bytes common header, followed by eCPRI payload, as shown in Figure 5. The common header contains an 1-bit indicator, as highlighted in Figure 5, which is used to indicate whether or not this eCPRI message is the last one in the PDU, implying if concatenation with subsequent messages is needed to form payload for the Transport Network Layer (e.g. UDP/IP, Ethernet).

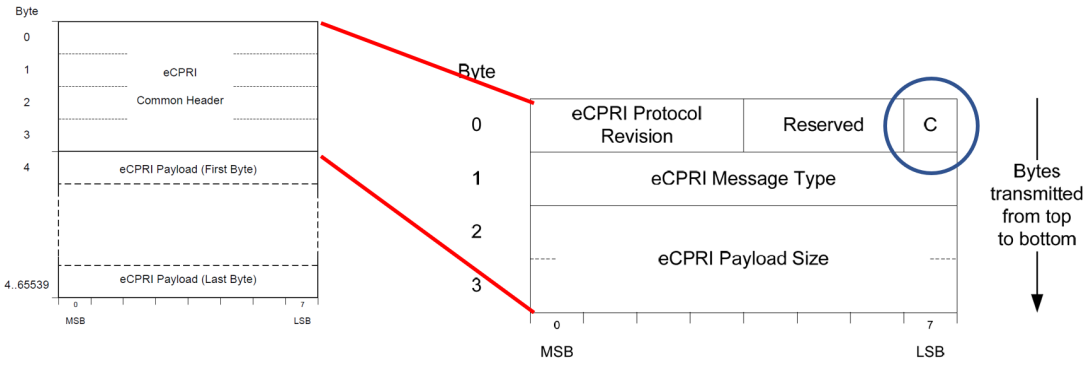

Figure 5: eCPRI common header.

Moreover, the eCPRI common header also comprises the information relating to message type, as the messages will be processed differently in accordance to its type. Each of these eCPRI message type is associating to a payload format, and is suitable for different functional split option. For instance, Message type 0 (IQ data) and Message type 1 (bit

sequence) are for intra-PHY functional split before and after IFFT operation (assuming downlink) respectively.

4.1.3 Contributions from 5G-Crosshaul

Three partners, namely Ericsson, Nokia and NEC, have been actively contributing to the eCPRI specifications. These contributions aligned with the work done in 5G-Crosshaul relating to requirements, QoS definition, and transport technology (e.g. compression, synchronization, etc.). As eCPRI standardization activities are not disclosed, it is hard to track and access all the input contributions and technical documents. Some 5 input contributions have been reported, and the full eCPRI specification as released has been reported by the partners to 5G-Crosshaul standardization achievement record.

4.2 Analysis of Achievements Over Entire Project Duration

Table 9 provides a summary of the input (normative) contributions that have been submitted by the consortium partners and reported to the 5G-Crosshaul standardization achievement record. A total of 35 input contribution and specification have been reported across several SDOs (eCPRI, ITU-T, IEEE, ETSI, IETF, ONF, BBF).

Table 9: Record of input (normative) contributions to SDOs.

SDO	**Year**			**Total**
	Year 1: Jul'15-Jun'16	Year 2: Jul'16-Jun'17	Year 3: Jul'17-Dec'17	
eCPRI	0	5	1	**6**
G.metro	5	0	0	**5**
IEEE	1	3	0	**4**
IMT-2020 FG	2	0	0	**2**
IRTF/IETF	1	7	0	**8**
ETSI MEC	4	0	0	**4**
ONF	0	4	0	**4**
BBF	2	0	0	**2**
			Total	**35**

From the above table, it is clear that eCPRI is the key specification released in Year 3 with direct contributions from 5G-Crosshaul partners for work aligned with the 5G-

Crosshaul concept. Significant contributions have also been made to ITU-T G.metro, IETF CCAMP, IETF DETNET, and ONF.

In addition to the above contributions of normative nature, Table 10 provides a record of dissemination activities of informative nature into the different standardization bodies. Some 25 standard dissemination contributions are reported in several SDOs noticeably ETSI, ONF, IEEE, NGMN, ITU-T, and BBF.

Table 10: Standardization dissemination (informative nature) record.

SDO	Year			Total
	Year 1: Jul'15-Jun'16	Year 2: Jul'16-Jun'17	Year 3: Jul'17-Dec'17	
3GPP	1	0	0	**1**
IEEE	3	1	0	**4**
ETSI	4	1	0	**5**
IETF/IERF	0	1	0	**1**
NGMN	2	1	0	**3**
ITU-T	1	2	0	**3**
BBF	2	0	0	**2**
ONF	2	3	0	**5**
FSAN	1	0	0	**1**
			Total	**25**

4.3 Liaison Activities with SDOs

The consortium has received a liaison request from IEEE 1914 in November 2017. The SDO has demanded the partners in 5G-Crosshaul to review the specifications of IEEE 1914, and provide the feedback based on the insight that the consortium has been obtained through the conducted research activities. Such solicitation by the IEEE is yet another example of the standardization impact of 5G-Crosshaul project.

4.4 Outline of Activities Planned After Project End

Standardization activities are dependent on the standardization timeline of a given SDO and hence they do not stop when the 5G-Crosshaul project stops. Therefore, we anticipate further standard contributions from the project partners wherever and

whenever a relevant specification activity in an SDO occurs. Continuous monitoring of the SDOs in technology areas relevant to 5G-Crosshaul is therefore expected after the project end to identify such future opportunities.

5 Exploitation Activities

It is undoubtedly crucial to identify the potential exploitation out of the results and concepts developed in this project. In particular, the key innovations, proof-of-concepts, commercial-grade products, and patents are some of the aspects that should be examined in terms of project exploitation. During the project execution over last two-and-half years, a multitude of activities have been carried out to exploit the values generated by this project, and this chapter aims to provide an overview in order to illustrate how well the findings of this project have been utilized to create commercial values. In this chapter, the key innovations, commercial products, and patents developed within the project will be summarised.

5.1 Key Innovations

Different key innovations have been identified at various components of 5G-Crosshaul framework. In this report, depending on the functional block where the technology is applied, the key innovations can be classified into following categories depending on the associated building blocks, namely XFE, XCI, and applications. The highlight of key innovations pertaining to each of these categories are summarised below. Partners within the consortium will make use of the EU free services for disseminating project results provided by the Common Dissemination Booster (CDB). For example, SME VISIONA plans to take advantage of Service 2 Stakeholder/end-user mapping to identify and prioritise stakeholders in the media sector and build the network VISIONA needs to reach them and exploit progress achieved behind TVBA application and the possibilities that VNF-based QoE monitoring offers for broadcasters.

Table 11: Key innovations pertaining to 5G-Crosshaul building blocks.

#	Building block	Innovation	Leading Partners
1	XFE	Novel optical ROADM based on integrated silicon photonics to reduce cost and size of 100 times with respect current nodes.	TEI
2	XFE	A latency reduction solution for mmWave-based backhaul/fronthaul dubbed fast-forwarding was developed, in order to support wireless transport for scenarios with stringent latency requirements (e.g. lower-layer split).	IDCC
3	XFE	Novel optical access solution for crosshaul services (Packetized FH) based on WS-WDM-PON technology is evaluated in a PoC where C-RAN schemes with different functional split options and SDN support are demonstrated in terms of 5G network requirements.	Telnet
4	XFE	Extension and evaluation of a Radio Resource Management algorithm for a dense deployment of small cells with mmWave transport capabilities powered with renewable energies based on distributed Q-learning. The agents placed at each small cell running this distributed algorithm will be able to improve the energy efficiency of	CTTC

		the system by learning from the local environment. Moreover, thanks to the activities in WP4, the agents can collaborate with EMMA application in order to include a system wide view which allows to guide the learning process towards a more energy efficient solution (e.g., by avoiding conflicts among the small cells agents in multi cells scenarios).	
5	XFE	Development of a SBI agent to provide a common abstraction of wireless data-plane resources. The proposed approach decouples control operations from management operations. Thanks to this decoupling, the solution offers the required flexibility to evolve with the evolution and the integration of multiple technologies in 5G-Crosshaul networks.	All WP2 partners
6	XFE	Network solution to use multi-layer nodes (packet and optical) to support tight requirements of latency and bandwidth.	All WP2 partners
7	XFE	Local OAM was added to the data plane to support its operation. Packets for connectivity checks or latency measurements cannot be injected into the network from the SDN controllers. Local OAM allows the XPFEs themselves to generate and receive the corresponding packets. The invention provides a corresponding state machine on the XPFEs, which is under control of the SDN controllers. This allows to get accurate information on the status of the network without placing a computational burden on the SDN controllers.	UC3M, IDCC
8	XFE	Procedures were defined to integrate safely new XPFEs into existing 5G-Crosshaul networks for cases where no out-of-band management network was available. The procedures are applicable to the general case as well as to XPFEs with wireless links only.	NOK-N, IDCC
9	XFE	Compressed packetized Fronthaul to reduce bandwidth requirements for CPRI.	EAB
10	XFE	Several fronthaul splits (MAC/PHY, PDCP/RLC) have been implemented on virtual machines and dedicated processor boards. The traffic according to different fronthaul splits can be generated without changing the underlying hardware and without having to apply for spectrum at the air interface. This eases considerable test setups to evaluate network configurations.	CND
11	XCI	In the control plane the VIM and the SDN controllers have been integrated to connect virtual machines in a data centre with other nodes in the Crosshaul network. The corresponding application allows the VIM to establish the network among virtual machines in data centres according to its own rules, e.g. regarding the use of VLANs. Thereafter the SDN controllers establish the connections inside the Crosshaul network using the information, which is provided by the VIM via the application.	NOK-N, NXW

12	XCI	A NFVO was developed, which is compliant to the ETSI NFV specifications and which allows to use different resource orchestration mechanisms. This NFVO allows to experiment with different optimization strategies to deploy VNFs in a data centre.	NXW
13	XCI	The hierarchical SDN control component of the XCI of different technological domains was shown in a PoC, covering three different transport domains (one optical and two wireless domains of different partners). The hierarchical SDN model allows through network abstraction to control multiple transport network domains and at the same time to encapsulate per-domain specific technological details in the corresponding child controllers. The developed XCI hierarchical control model decreases the e2e service provision time while increasing the XCI scalability in terms of number of managed domains transporting both fronthaul and backhaul traffic, hence easing the integration of different technological transport domains.	CTTC, IDCC
14	Applications	An SDN application featuring graphical interface and the logic to manage requests for energy efficient paths and monitor power consumption per entity.	NXW
15	Applications	TV Broadcasting application (TVBA) – An application running as an OTT service whose purpose is to provide TV broadcasting and multicasting services through the 5G-Crosshaul network maintaining optimal QoS and QoE at user's reception.	VISONA
16	Applications	Content Delivery Network Management application (CDNMA) – A Web application comprising algorithms for management and implementation of CDN in 5G-Crosshaul network, including vCDN infrastructure instantiation, and control and management of the service during its lifetime.	ATOS
17	Applications	Resource Management application (RMA) – An application featuring algorithms for providing a centralized and automated management of 5G-Crosshaul resources, to promptly provision transport services with an adequate quality while ensuring that resources are effectively utilized. The application provides support to the VoD and live streaming services (provided by the CDNMA and TVBA applications) by provisioning the optimal path for mobile users' traffic.	NEC CREATE-NET
18	Applications	Mobility Management application (MMA) – An application based on Distributed Mobility Management (DMM) for traffic offloading optimization for media distribution like CDN and TV Broadcasting.	ITRI UC3M

5.2 Commercial Products

Table 12 summarises the commercial products relating to transport networks that have been released by some of the main vendors in the consortium.

Table 12: List of products relating to technologies in the scope of 5G-Crosshaul.

Innovation	PoC / Product / Service	Partner
XFE Packet	eNB with flexible functional split PoC	CND
	Radio Dot System	Ericsson
	Router 6000 family	
	EdgeLink mmWave nodes	InterDigital
	Fast-Forward mmWave nodes	
	iPASOLINK converged packet radio	NEC
	Flexi Multiradio 10 Base Station	Nokia
	Ethernet VLAN switch	
	AnyHaul	
	SDN WS WDM PON solution	Telnet
XFE Circuit	Fronthaul 6000	Ericsson
	Optical forwarding elements	
	AnyHaul	Nokia
XCI	OpenEPC	CND
	Wireless SDN Transport PoC	Ericsson NEC Telefonica
	Services SDN	Ericsson
	Cloud System	
	Network Manager	
	EdgeHaul SDN-based controller	InterDigital
	vEPC	NEC
	ProgrammableFlow controller	

	SDN/NFV PoC	Nextworks
	HetNet solution	Nokia
	WDM SDN controller	Telnet
	CDN	ATOS
Network Apps	TV broadcasting – QoE monitoring in the cloud	Visiona
	Energy efficiency management and monitoring	Nextworks / Polito
	Mobility management	UC3M / ITRI

5.3 Patents

Table 13 lists 4 patent applications that have developed and reported by consortium partners during the execution phase of the project. An additional three invention disclosures with references NC104517, NC104518, NC104519 have also been reported by Nokia, pending internal approval for filings.

Table 13: List of patent applications reported into 5G-Crosshaul.

#	Patent Application Number and Title	Partner
1	WO2017088902: Ethernet frames encapsulation within CPRI basic frames	NEC, UC3M
2	WO2017142862: Open flow functionality in a software-defined network	IDCC
3	WO2017147076: Methods, apparatuses and systems directed to common transport of backhaul and fronthaul traffic	IDCC
4	WO2017204704: Method, decoder, and encoder for handling a bit stream for transmission over a transmission link between a remote unit and a base unit of a base station system	EAB

6 Conclusions

This deliverable reported the achievements of 5G-Crosshaul in terms of communication, dissemination, collaboration, standardization and exploitation activities, both in Year 3 (from 1 July 2017 to 31 December 2017) and cumulatively throughout the project lifetime (from 01 July 2015 to 31 December 2017). It is crystal clear that the project has exceeded all targeted objectives for Year 3 and throughout the project lifetime. An impressive record across a diverse set of activities has been achieved.

Specifically, for Year 3, the main achievements lie in: (1) the release of eCPRI standard specification including contributions from 5G-Crosshaul partners; (2) the boosting of the publications and dissemination record with additional 17 publications, 10 talks, and 2 workshops organized; and (3) producing videos and video interviews on various demonstrations showcasing the technological innovations developed within the project.

Cumulatively throughout the project execution, the project developed some 20 technological innovations reported in this deliverable and deployed a wide range of communication, dissemination and exploitation tools to maximize the impact of these innovations on all stakeholders. This can be appreciated from the highlights below:

- Over 35 normative contributions feeding into key standardization specifications such as: eCPRI, G.metro, IETF CCAMP, IETF DETNET, and ONF. This is in addition to some 25 (informative) dissemination activities in standardization bodies and forums such as NGMN, ITU-T, FSAN, ETSI, IEEE, BBF, ONF.
- Nearly 100 peer-reviewed publications in IEEE and ACM proceedings, journals and magazines, over 75 talks and panels delivered at key events, and nearly 15 workshops and special sessions (co-) organized.
- Over 25 demonstrations exhibited at various events including at the flagship Mobile World Congress (MWC) both in 2016 and 2017 and at the EC conference EuCNC in 2016 and 2017.
- Some 5 patent applications developed and reported by the project consortium.
- Proactive communication through blogs, press releases, video interviews, and leaflets, all actively promoted through various channels.

Further activities will continue beyond the project lifetime noticeably in terms of communication for the shorter term for example to accompany MWC'18, and in terms of standardization and exploitation activities in the medium and longer terms. Partners within the consortium will also make use of the EU free services for disseminating project results provided by the Common Dissemination Booster (CDB). Up to five services will be available for 5G-Crosshaul members during 2018 to maximize the reach and impact of the innovations developed in the project.

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