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

D6.1: Report on the dissemination, communication and exploitation activities during the first year of the project

Abstract

This deliverable (D6.1) reports on all the activities undertaken in WP6 in the first year of the project, i.e. from 1st of July 2015 to 30th of June 2016. It also provides an outline of the work plan for Year 2, building on the momentum reached in Year 1 and the anticipated technical developments in Year 2.

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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
CPRI	Common Public Radio Interface
CSA	Coordination and support Action
DetNet	Deterministic Networking (IETF)
EPC	Evolved Packet Core
ETP	European Technology Platform
ETSI	European Telecommunications Standards Institute
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
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)
MAG	Magazine dissemination
MEC	Mobile Edge Computing
MPLS	Multiprotocol Label Switching
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
PoC	Proof of Concept
PON	Passive Optical Network
QoS	Quality of Service
RAN	Radio Access Network
RE	Radio Equipment
RNC	Radio Network Controller
RoE	Radio Over Ethernet
RoF	Radio Over Fibre
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
VNF	Virtual Network Function
WDM	Wave Division Multiplexing
WG	Working Group
XCI	Xhaul Control Infrastructure
XGPON	10Gbit/s-capable PON

Executive Summary

5G-Crosshaul's ultimate goal is to generate a maximum impact for its innovations. Towards this goal, the 5G-Crosshaul project has invested tremendous efforts in Year 1 to communicate and disseminate the project vision, concept, and first year results, to all stakeholders in the wide international community. Particular efforts have been put on standardization and exploitation activities with the aim to facilitate and accelerate the creation of an industrial impact. Amongst the key achievements in Year 1 are:

- A noticeable presence at flagship events such as Mobile World Congress 2016, with partners providing 4 demonstrations relating to 5G-Crosshaul project, as well as video interviews and project elevating pitches and materials.
- An active promotion of the 5G-Crosshaul project in standardization forums such as European Telecommunications Standard Institute (ETSI), International Telecommunications Union - Telecommunications standardization sector (ITU-T), Next Generation Mobile Networks (NGMN) and Institute of Electronics and Electrical Engineering (IEEE), through presentations and input contributions. Over 25 standardization materials have been delivered in Year 1, thus an average of (approx.) 2 materials per month. Noticeably, the project presented its standardization roadmap for the 5G integrated fronthaul and backhaul at ETSI in May 2016, with the aim to identify and address potential standardization gaps.
- An active communication and dissemination of the project through (over 35) invited talks, (over 5) organized workshops, and (over 5) videos at key events.
- A good record of scientific peer-reviewed publications with over 30 articles published or accepted for publication (and several others submitted) in reputed journals and conference/workshop proceedings.
- A proactive identification of key innovations from the project with possible paths for exploitation in products and services.

In addition to the above, an outline of the work plan for Year 2 has been developed and shared in this deliverable.

1 Introduction

This document reports on the achievements of the 5G-Crosshaul project in Year 1 for all communication, dissemination, standardization and exploitation activities. It also outlines a work plan for these activities in Year 2.

The document is structured into four main chapters, 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 1, and outlines the corresponding work plan for Year 2. These activities are steered towards ensuring an up-to-date communication on the project to the large public through various channels including portal, social networks, videos, and magazine articles.

Chapter 3 reports on the dissemination activities including talks, workshops, and peer-reviewed scientific articles. It also reports on related collaboration activities undertaken in the framework of the 5G-PPP including its projects and working groups. The goal of such activities is mainly to promote the project to the Research & Development (R&D) stakeholders, and raise opportunities for collaboration or synergy with other projects and activities.

Chapter 4 reports on the standardization activities undertaken and presents the standardization roadmap developed in the project. These activities are aimed at creating an influence from/to ongoing or future standardization activities so that the technology developed in the project can find an easier path for exploitation into future products.

Chapter 5 reports on the exploitation activities undertaken with the aim to identify innovations from the project that can find venues for exploitation in products, proof-of-concepts, and services.

The document ends with conclusions summarizing the work done in Year 1, and insights on the next steps planned in Year 2.

2 Communication and Public Activities

Communication activities undertaken in Year 1 have been steered towards ensuring an up-to-date communication on the project concept and first results to the large public through various tools including web portal, social networks, video interviews, leaflet, and magazine articles. This chapter provides first the Year 1 plan set for communication activities and reports next on the subsequent achievements. It then concludes with the next steps planned for Year 2 of the project.

2.1 Work Plan for Year 1

The focus in Year 1 has been put on raising and fostering awareness of the 5G-Crosshaul project vision, concept, objectives, and first initial results, amongst the various stakeholders (R&D community, market players, and the general public). The following objectives were set:

- Deployment of the project portal for an up-to-date communication on all events and milestones from the project to the wide community.
- Deployment of social networks accounts to complement with the project portal.
- Delivery of video interviews and magazine articles for promoting the project vision, concept and initial results.
- Issuing of a press release announcing the project kick-off.
- Preparing a first project leaflet reflecting on the project concept and first results in time for communication at the Mobile World Congress 2016.

2.2 Report on Activities Undertaken and Achievements

Following the project kick-off on July 1, 2015, activities have been undertaken towards fulfilling the objectives set above. These are reported in Table 1, Table 2, and Table 3, respectively for activities relating to (1) project portal and social networks, (2) video interviews and blog articles, and (3) press releases and leaflets. Additional activities prior to the project kick-off are reported in Appendix A.

Table 1: Project portal and social networks.

#	Month	Description	Lead partners
1	Jul'15	Release of 5G-Crosshaul project portal www.5g-crosshaul.eu	UC3M
2	Jul'15	Set up of twitter @xhaul_eu and 5G-Crosshaul LinkedIn group	UC3M
3	Throughout Y1	Constant update of the project website with contents on the talks, workshops, demonstrations, and events undertaken and planned. It has been given free access to download public presentations and materials from the partners, subject to partner permission.	UC3M, IDCC

4	Throughout Y1	Synchronicity between project website and the social media news shared on the project Twitter and LinkedIn accounts.	UC3M, IDCC

Table 2: Video interviews and blog articles.

#	Month	Description	Lead partners
1	Jul'15	Video interview provided by Project Coordinator to 5G Public Private Partnership Coordination and Support Action (5G PPP CSA), http://5g-crosshaul.eu/5g-ppp-xhaul-project-video-shot-at-eucnc2015/	UC3M
2	Jul'15	RCR Wireless article "5G is coming! Wireless telecom is dead, long live wireless IT", by IDCC promoting in part the project vision of flexible backhaul and fronthaul integrated solution.	IDCC
3	Sep'15	RCR Wireless article "5G is coming! Dissecting the 5G RAN where Flexibility and Fine Integration will be King", by IDCC promoting explicitly the projectl vision, concept and ambition as part of the overall RAN picture of the 5G system	IDCC
4	Oct'15	Project presentation in ATOS Research and Innovation booklet circulated to company partners and clients.	ATOS
5	Oct'15	Video demonstration at the GSMA Mobile 360 series (http://www.mobile360series.com/) on the base platform used to implement and test different RAN as a Service and novel mobility concepts.	UC3M
6	Feb'16	4 video interviews on the demonstrations shown at Mobile World Congress 2016 (available at www.5g-crosshaul.eu)	IDCC, HHI, CTTC, CND
7	Apr'16	Atos has highlighted Crosshaul as a key project in an article describing Atos' participation in 5G projects. This article has been published through Atos' internal communication channels and is visible by circa 100.000 employees worldwide.	ATOS
8	Jun'16	Video interview at Computex Taipei 2016 in Taiwan by ITRI	ITRI
9	Jun'16	Video interview by the Project Coordinator to 5G PPP CSA at EUCNC 2016	UC3M

Table 3: Press releases and leaflets.

#	Month	Description	Lead partners
1	Jul'15	First press release announcing the project kick-off, its vision, ambition, objectives and consortium. http://5g-crosshaul.eu/xhaul-kick-off/ The press release was also followed by related communications from most of the partners as reported in Appendix A.	IDCC, UC3M

2	Feb'16	First project leaflet along with elevator pitch slides for MWC 2016. The leaflet is shown in Figure 1.	IDCC, UC3M

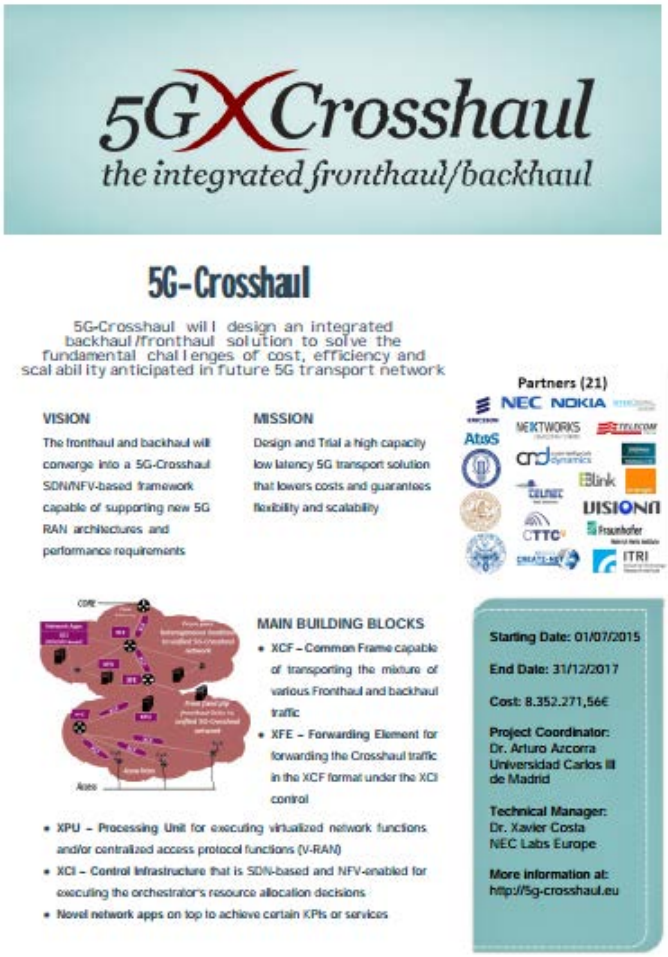

Figure 1: Illustration of the first 5G-Crosshaul leaflet.

Furthermore, in order to avoid any potential confusion from the very similar names of our project Xhaul (now 5G-Crosshaul) and the project 5G-XHaul, our project has taken the initiative to clarify the areas of overlap and differences with respect to the 5G-XHaul project and published this overview on the project website [1]. The leading partner for this task has been NEC (the technical manager).

Our project's approved change of name from Xhaul to 5G-Crosshaul has been transitioned smoothly with all accounts and web links (e.g. website, social media, private area, etc.) updated from day 1 of the approval, and new logos and templates made available for immediate use in the various communication and dissemination activities. The leading partner for this task has been UC3M (the project coordinator).

Finally, the 5G-Crosshaul project has appointed a representative (IDCC, WP6 manager) for liaison with the 5G-PPP communication and dissemination working group, where news and events from 5G-Crosshaul are shared within the 5G-PPP.

2.3 Work Plan for Year 2

Building on the momentum reached in Year 1, and the anticipated technology development including trials in Year 2, the project plans to accompany these developments with the adequate communication activities including:

- Video and a press release for the first trial scheduled in September 2016 in Berlin. Videos for subsequent trials are also to be considered.
- Video interviews and second leaflet in time for MWC 2017 in Barcelona.
- Additional video interviews and blog articles more focused on the innovations outcome of the project as they happen in year 2.
- Continuous communication through the project portal, the social networks, and the 5G-PPP communication and dissemination working group.

3 Dissemination and Collaboration Activities

Dissemination and Collaboration (primarily within the 5G-PPP) activities have been conducted in Year 1 in order to help promote the project concept and initial results to the large European and more International R&D community, and raise opportunities for synergy with other projects and activities. This chapter presents first the plan set in Year 1 and reports next the related achievements for dissemination and collaboration activities respectively. An outline of the plan for Year 2 is then provided.

3.1 Work Plan for Year 1

The high level objectives for dissemination and collaboration activities in Year 1 were defined as follows:

- To raise and foster awareness of the project vision, concept, objectives, and first initial results, amongst the R&D community.
- To establish synergy links with other related projects, in particular within the 5G-PPP programme, with the aim of promoting a coherent overall 5G architecture and developing consistent technology building blocks.

It is worth noting that the above objectives are not restricted to Year 1 only, but will remain applicable over the whole project duration.

From the above high level objectives, the project has set specific and measurable objectives for dissemination and collaboration activities.

3.1.1 Dissemination Work Plan for Year 1

The dissemination activities will be steered towards generating impact through peer-reviewed publications, presentations, talks, demonstrations, panels, workshops, and events. The goals set in Year 1 include:

- Delivery of at least 10 talks promoting the project vision, concept and initial results at selected R&D events and industry summits.
- Demonstration of project related prototypes or solutions at least at 2 R&D industry showcases.
- Organization of at least 1 R&D event in Asia to promote the work, leveraging ITRI's participation into the project.
- Submission of at least 15 scientific articles for publication at reputed conferences and journals.
- Addition of core skills for technology development within the project into academic curriculums, along with the proposal of PhD and MSc theses on specific topics on 5G-Crosshaul's research agenda.

3.1.2 Collaboration Work Plan for Year 1

The collaboration activities will target the establishment of synergy links with other relevant research actions, projects, and alliances, in particular within the framework of

European H2020 Information and Communication Technology (ICT) research focused on next generation communication networks. The activities planned in Year 1 include:

- Establishment of synergy links to other H2020 5G-focused projects, in particular projects within the 5G PPP. Four 5G PPP projects have been identified for potential synergies with our project, namely, NORMA, 5G-XHaul, SONATA and 5GEx. The areas of overlap and differentiation will be analysed and used to better steer the collaboration efforts with these projects.
- Participation into the 5G PPP CSA activities aimed at federating the efforts from all projects into an executable work programme. The activities include meetings, workshops, white papers, etc. Towards this objective, the consortium appointed representatives to the CSA working groups, as listed in Table 4 below.
- Participation into the European Technology Platform (ETP) NetWorld2020 with the aim to trigger collaboration within the community on ongoing research relevant to the project but also potential future research directions. Towards this objective, the coordinator UC3M is chairing the ETP NetWorld2020 and will be leading the project participation in this ETP.

Table 4: Project representatives in the 5G PPP CSA working groups.

5G PPP CSA working group	5G-Crosshaul representative
Vision & Societal Perspective	TI
Architecture	NEC
Software Networks	NOK-N
Network Management, QoS and Security	TEI
Pre-standards	IDCC
Spectrum	UC3M

3.2 Report on Activities Undertaken and Achievements

The dissemination and collaboration activities and achievements for Year 1, from July 2015 to June 2016, are reported in the following sub-sections. Activities prior to the project kick-off are reported in Appendix B.

3.2.1 Dissemination Activities

Table 5 lists all peer-reviewed publications in Year 1. Published or accepted for publication materials are reported. As reported, the project has published over 30 peer-reviewed articles in Year 1, with a few more already accepted for publication at the start of the Year 2. This gives an average of approx. 2.5 papers published or accepted a month.

Table 5: Peer-reviewed publications in Year 1.

#	Type	Month	Description	Leading Partner
1	CNF	Sep'15	"Outage Probability of Beamforming for Multiuser MIMO Relay Networks with Interference", by S. Zhou, G. Alfano, C.F. Chiasserini, A. Nordio, at IEEE APWC, Turin, Italy.	POLITO
2	CNF	Oct'15	"Future Generation of Wireless Communication Systems: requirements and open issues", by F. Testa, F. Cavaliere, R. Sabella, at Microwave Photonics workshop at ECOC 2015, Valencia, Spain.	TEI
3	MAG	Nov'15	"Xhaul: Towards an Integrated Fronthaul/Backhaul Architecture in 5G Networks", by A. de la Oliva, X. Costa, A. Azcorra, A. Di Giglio, F. Cavaliere, D. Tiegelbekkers, J. Lessmann, T. Haustein, A. Mourad, P. Iovanna, at IEEE Wireless Communications Magazine, Special Issue on Smart Backhauling and Fronthauling for 5G Networks.	NEC, TEI, NOK-N, FhG-HHI, IDCC
4	CNF	Nov'15	"A Service-based model for the Hybrid Software Defined Wireless Mesh Backhaul of Small Cells", by J. Núñez, J. Baranda, J. Mangues, at 2nd International Workshop on Management of SDN and NFV Systems (ManSDN/NFV) in conjunction with 11th International Conference on Network and Service Management (CNSM15), Barcelona, Spain.	CTTC
5	CNF	Nov'15	"What role for Photonics in Xhaul Networks of 5G systems?", by P. Castoldi, L. Valcarenghi, F. Cugini, F. Cavaliere, P. Iovanna, at Asia Communications and Photonics Conference, Hong Kong.	TEI
6	JRN	Dec'15	"Software-Defined Wireless Transport Networks for Flexible Mobile Backhaul in 5G System", by D. Bercovich, L.M. Contreras, Y. Haddad, A. Adam, C.J. Bernardos, at ACM/Springer Mobile Applications and Networks, Special Issue on "Recent Advances on the Next Generation of Mobile Networks and Services".	TID, UC3M
7	CNF	Jan´16	"Coexistence of IEEE 802.11n and Licensed-Assisted Access devices using Listen-before-Talk techniques", by Claudio Casetti, at 13th IEEE Annual Consumer Communications & Networking Conference (CCNC), Las Vegas, USA.	POLITO
8	CNF	Jan´16	"A System-level Assessment of Uplink CoMP in LTE-A Heterogeneous Networks", by MT Sanij, Claudio Casetti, at 13th IEEE Annual Consumer Communications & Networking Conference (CCNC), Las Vegas, USA.	POLITO
9	CNF	Jan´16	"Mobility-Aware Edge Caching for Connected Cars", by A. Mahmood, C. Casetti, C.F.Chiasserini, P. Giaccone, J. Härri, at the 12th Wireless On-	POLITO

			demand Network Systems and Services Conference (WONS) 2016, Cortina d'Ampezzo, Italy.	
10	MAG	Feb´16	"An Overview of the CPRI Specification and Its Application to C-RAN-Based LTE Scenarios", by A. Oliva, J.A. Hernández, D. Larrabeiti, and A. Azcorra, at IEEE Communications Magazine.	UC3M
11	MAG	Mar´16	"The CTTC 5G end-to-end experimental platform: Integrating heterogeneous wireless/optical networks, distributed cloud, and IoT devices", R. Muñoz et al., IEEE Vehicular Technology Magazine.	CTTC
12	CNF	Mar'16	"Hierarchical SDN Orchestration of Wireless and Optical Networks with E2E Provisioning and Recovery for Future 5G Networks", by R. Vilalta et al., at the Optical Fiber Communication Conference and Exhibition (OFC), Anaheim, California (USA)	CTTC
13	CNF	Mar'16	"Performance Demonstration of Fiber and Wireless Fronthaul Combination with Remote Powering" by Z. Tayq et al. OFC 2016, Los Angeles, California (USA)	ORANGE
14	JRN	Apr´16	"Mobility Management: Deployment and Adaptability Aspects Through Mobile Data Traffic Analysis", by MI. Sanchez, E. Zeydan, A. de la Oliva, AS. Tan, U. Yabas and CJ. Bernardos, at Computer Communications, 2016	UC3M
15	CNF	May'16	"Orchestration of IT/Cloud and Networks: From Inter-DC Interconnection to SDN/NFV 5G Services", R. Casellas, R. Muñoz, R. Vilalta, R.Martínez, at 20th Conference on Optical Network Design and Modeling (ONDM 2016), Cartagena, Spain.	CTTC
16	CNF	May´16	"Time-Domain Precoding for LTE-over-Copper Systems", by Y. Huang, E. Medeiros, T. Magesacher, S. Host, C. Lu, P. Eriksson, P. Odling and P. Ola Borjesson, ICC 2016, Kuala Lumpur, Malaysia.	ULUND, EAB
17	CNF	May´16	"Dynamic Strict Fractional Frequency Reuse for Software-Defined 5G Networks", by Anteneh A. Gebremariam, Tingnan Bao, Domenico Siracusa, T. Rasheed, F. Granelli and L. Goratti, ICC 2016, Kuala Lumpur, Malaysia.	CREATE-NET
18	CNF	May´16	"Markovian Models of Solar Power Supply for a LTE Macro BS", by G. Leonardi, M. Meo, M. Ajmone Marsan, ICC 2016, Kuala Lumpur, Malaysia.	POLITO
19	JRN	May´16	"Crosstalk Mitigation for LTE-over-Copper in Downlink Direction", by Eduardo Medeiros, Yezi Huang, Thomas Magesacher, Stefan Höst, Per-Erik	ULUND, EAB

			Eriksson, Chenguang Lu, Per Ödling and Per Ola Börjesson, in IEEE Communications Letters	
20	CNF	Jun´16	"WiseHAUL: An SDN-empowered Wireless Small Cell Backhaul testbed", by J. Núñez-Martínez, J. Baranda, I. Pascual, J. Mangues-Bafalluy, Seventeenth International Symposium on a World of Wireless, Mobile and Multimedia Networks (WOWMOM) 2016, Coimbra, Portugal.	CTTC
21	CNF	Jun´16	"Downlink Transmit Power Setting in LTE HetNets with Carrier Aggregation", by ZI. Fazliu, CF. Chiasserini, GM. Dell'Aera, at Seventeenth International Symposium on a World of Wireless, Mobile and Multimedia Networks (WOWMOM) 2016, Coimbra, Portugal. Best paper award.	POLITO, TI
22	CNF	Jun'16	"Fronthaul Performance Demonstration in a WDM-PON-Based Convergent Network", by Z. Tayq et al., at EUCNC 2016, Athens, Greece.	ORANGE
23	CNF	Jun'16	"Packet Forwarding for Heterogeneous Technologies for Integrated Fronthaul/Backhaul", by T. Deiss et al., at EUCNC 2016, Athens, Greece.	NOKIA, UC3M, NEC,IDCC, TEI, NEXTWORKS
24	CNF	Jun'16	"Orchestration of Crosshaul Slices From Federated Administrative Domains", by LM. Contreras, CJ. Bernardos, A. de la Oliva, X. Costa, R. Guerzoni, at EUCNC 2016, Athens, Greece.	TID, NEC, UC3M, CTTC
25	CNF	Jun'16	"5G-Crosshaul: Towards a Unified Data-Plane for 5G Transport Networks", by L. Cominardi, J. Baranda, D. Larrabeiti, F. Cavaliere, P. Chanclou, J. Gomes, A. Di Giglio, P. Ödling, HW. Chang, at EUCNC'16, Athens, Greece.	IDCC, UC3M, CTTC, TI, TEI, ORANGE, LUND, ITRI, HHI
26	CNF	Jun'16	"Innovations Through 5G-Crosshaul Applications", by Xi Li et al., at EUCNC'16, Athens, Greece.	NEC, NEXTWORKS, CTTC, POLITO, ATOS, CREATE-NET, VISIONA, TID
27	CNF	Jul'16	"The Price of Fog: a Data-Driven Study on Caching Architectures in Vehicular Networks," by F. Malandrino, CF. Chiasserini, S. Kirkpatrick, accepted at the ACM MobiHoc Workshop on	POLITO

			Internet of Vehicles and Vehicles of Internet (IoV-VoI), Paderborn, Germany.	
28	CNF	Jul´16	"SDN/NFV Orchestration of Multi-technology and Multi-domain Networks in Cloud/Fog Architectures for 5G Services", by R. Vilalta, A. Mayoral, R. Casellas, R. Martínez, R., at 21st Optoelectronics and Communications Conference / International Conference on Photonics in Switching (OECC/PS) 2016, Niigata, Japan.	CTTC
29	CNF	Sep'16	"Efficient Multimedia Broadcast for Heterogeneous Users in Cellular Networks", by C. Singhal, CF. Chiasserini, CE. Casetti, accepted at the 12th IEEE International Wireless Communications & Mobile Computing (IWCMC 2016), Paphos, Cyprus, September 5-9, 2016.	POLITO
30	JRN	Sep'16	"5G-Crosshaul: An SDN/NFV Control and Data Plane Architecture for the 5G Integrated Fronthaul/Backhaul", S. González, A. de la Oliva, X. Costa, A. Di Giglioz, F. Cavalierex, T. Deiss, X. Li, A. Mourad, at Transactions on Emerging Telecommunications Technologies.	UC3M, NEC, NOK-N, TEI, TI IDCC
31	CNF	Sep'16	"Performance Demonstration of Real Time Compressed CPRI Transport", by Z. Tayq et al., ECOC 2016, Düsseldorf, Germany	ORANGE
32	CNF	Sep'16	"Experimental Real Time AMCC Implementation for Fronthaul in PtP WDM-PON" by Z. Tayq et al., ECOC 2016, Düsseldorf, Germany	ORANGE
33	CNF	Sep'16	"Experimental Investigation of Compression with Fixed-length Code Quantization for Convergent Access-Mobile Networks", by TBD, ECOC 2016 (poster), Düsseldorf, Germany	ORANGE

Additional materials were also published as the result of 3 master thesis conducted by the partner POLITO, as reported in Table 6.

Table 6: Additional dissemination materials published in Year 1.

1	THES	Jul'15	"Traffic Steering in Wireless Systems through Software Defined Networking", MSc thesis.	POLITO
2	THES	Jun'16	"Simulation of Energy Management Functions in 5G Networks", Advised by C. Casetti	POLITO
3	THES	Jun'16	"Development of Monitoring Mechanisms for Energy Efficient 5G Networks", Advised by CF. Chiasserini.	POLITO

Table 7 lists all presentation activities delivered including talks and panels. As reported, more than 36 activities are delivered in Year 1, averaging 3 per month.

Table 7: Talks and panels delivered in Year 1.

#	Month	Description	Leading Partner
1	Jul'15	"The Xhaul Project", by A. de la Oliva, at the special session on 5G PPP projects, EuCNC 2015, Paris, France.	UC3M
2	Sep'15	R. Vilalta, et al, "A Research Perspective for SDN Orchestration", IIR Network Virtualization Forum, Madrid, Spain, invited talk, September 2015.	CTTC
3	Sep'15	N. Zein, "Transport Network Evolution towards 5G Solutions and Standardisation" at the Layer123 - Packet Microwave & Mobile Backhaul, London, 22 September 2015.	NEC
4	Sep'15	F. Chen, "METIS II and 5G-Crosshaul Projects in 5G PPP", 2015 Taipei 5G Summit and co-organization of the event, Taipei, 22 September 2015, Taiwan.	ITRI
5	Sep'15	J. Mangues, "Programmable Mobile Networks: Why? What? How?", the 7th EAI International Conference on Mobile Networks – Keynote.	CTTC
6	Sep'15	P. Chanclou, "Changes, Challenges and Case Studies in the Fronthaul Network for C-RANs", RAN world event, Cologne, Germany, 29-30 September 2015.	ORANGE
7	Nov'15	L. M. Contreras Murillo, "5G Backhauling", Workshop on Radio and Core Network within the 6th FOKUS FUSECO Forum, Berlin, Germany, 5 November 2015.	TID
8	Nov'15	"Resource Management in 5G Transport Networks", by D. Siracusa, at the COMBO Workshop within the 12th Conference of Telecommunication, Media and Internet Techno-Economics (CTTE), Munich, Germany.	CREATE-NET
9	Nov'15	"Millimetre-wave in 5G-Crosshaul" by J. Mangues-Bafalluy, at the TWEETHER project workshop, Valencia, Spain.	CTTC
10	Nov'15	"NEC Vision and R&D Activities towards 5G", by X. Costa Perez, at the IEEE 5G Summit, Toronto, Canada.	NEC
11	Nov'15	"5G-Crosshaul and the Mobile Edge", by D. Castor, at the IEEE pre-industrial workshop on Mobile Edge Cloud, New Jersey, USA.	IDCC
12	Dec'15	"5G Technologies: An introduction", by A. Mourad, at the NGMN IPR workshop on 5G Technologies, Vienna, Austria.	IDCC
13	Jan´16	"5G-Crosshaul Architecture Overview", by X. Costa, at the 5GPPP Workshop on 5G RAN Design, Valencia, Spain.	NEC
14	Jan´16	"Self-backhauling in 5G", by A. Mourad, at the 5GPPP Workshop on 5G RAN Design, Valencia, Spain.	IDCC
15	Jan´16	"Connectivity in 2018 – Fronthaul and Backhaul Challenges for 5G", by X. Costa, at the Germany Connect 2016 Conference, Frankfurt, Germany.	NEC
16	Jan´16	"Opportunities and Challenges for Wireless Fronthaul/Backhaul", by D. Castor, at IWPC workshop on Evolved Transport Networks, Verizon, USA.	IDCC

17	Jan´16	"Coexistence of IEEE 802.11n and Licensed-Assisted Access Devices using Listen-before-Talk Techniques", by C. Casetti, at the IEEE CCNC 2016, Las Vegas, USA	POLITO
18	Jan´16	"A System-level Assessment of Uplink CoMP in LTE-A Heterogeneous Networks", by C. Casetti, at the IEEE CCNC 2016, Las Vegas, USA.	POLITO
19	Feb´16	"EU 5GPPP Project: 5G-Crosshaul The 5G Integrated Fronthaul/Backhaul", by X. Li, at the ITG 5.2.1 Workshop at NEC Laboratories, Heidelberg, Germany	NEC
20	Feb'16	"Distributed multi-tenant cloud/fog and heterogeneous SDN/NFV orchestration for 5G services," by Ricard Vilalta et al. Catalan Pavilion, Mobile World Congress 2016, Barcelona, Spain.	CTTC
21	Mar´16	"5G-Crosshaul Project Overview", by B.K. Lim, at the NGMN Forum meeting, Taipei, Taiwan	IDCC
22	Mar'16	"Mobile Edge Network for Wireless 5G", by F.C. Chen, at the NGMN Forum meeting, Taipei, Taiwan	ITRI
23	Mar'16	"5G-Crosshaul: The 5G Integrated Fronthaul/Backhaul", by L.M. Contreras Murillo, at ETSI MEC ISG #17 meeting, Madrid, Spain.	TID
24	Apr'16	"5G-Crosshaul: The 5G Integrated Fronthaul/Backhaul", by P.H. Kuo, at the ETSI workshop (5G: from myth to reality), Sophia-Antipolis, France	IDCC UC3M
25	Apr´16	"5G Roadmap to Backhaul and Fronthaul integration and 2016 Trial plans", by A. Mourad, at IWPC Workshop on 5G Trials and Initiatives towards 2020, Seoul, South-Korea.	IDCC
26	May'16	"5G Transport Networks - IEEE ICC 2016 - Workshop Next Generation Backhaul/Fronthaul Networks", panel organization by X. Costa-Perez, at IEEE ICC 2016, Kuala Lumpur, Malaysia.	NEC
27	May'16	"Moving Optical Dynamicity to the Edge" by Juan Pedro, at the 20th International Conference on Optical Network Design and Modeling (ONDM 2016), Cartagena, Spain.	TID
28	May'16	"Control Plane for High Capacity Networks", by Luis Miguel Contreras, 5th International Workshop on Trends in Optical Technologies, Campinas-São Paulo, Brazil	TID
29	May'16	"Standardization Roadmap for the 5G Integrated Fronthaul and Backhaul", by A. Mourad, at ETSI workshop (5G from research to standardization), Sophia-Antipolis, France.	IDCC
30	Jun'16	"Fronthaul Requirements of 5G Mobile Networks", by T. Deiss, at the EUCNC 2016 workshop Towards Converged X-Haul for 5G Networks, Athens, Greece.	NOK-N
31	Jun'16	"Bit-Rate Bound Derivation for Compressed Time-domain Fronthaul", by C. Lu, at the EUCNC 2016 workshop Towards Converged X-Haul for 5G Networks, Athens, Greece.	EAB
32	Jun'16	"Ethernet OAM and SDN: A Matching Opportunity", by L. Cominardi, at EUCNC 2016 workshop Network Function Virtualisation (NFV) and Programmable Software Networks, Athens, Greece.	IDCC

33	Jun'16	"5G-Crosshaul: A 5G Integrated Backhaul and Fronthaul Flexible Transport Network", by F. Cavaliere, at the EUCNC 2016 workshop Next Generation fronthaul/backhaul integrated transport networks, Athens, Greece.	TEI
34	Jun'16	"5G-Crosshaul Concept and Architecture", by X. Costa-Perez, at the EUCNC 2016 workshop Next Generation fronthaul/backhaul integrated transport networks, Athens, Greece.	NEC
35	Jun'16	"5G-Crosshaul Control and Data planes", by T. Deiss, at the EUCNC 2016 workshop Next Generation fronthaul/backhaul integrated transport networks, Athens, Greece.	NOK-N
36	Jun'16	"Softwarization in 5G Mobile Networks", by Tinku Rasheed, IEEE Lecture Series	CREATE-NET
37	Jun'16	J.P. Fernández-Palacios, "Crosshaul Innovation" (tentative title) in Optical Innovation Forum, hosted by Huawei and Heavy Reading, co-located to IIR's WDM & NG Optical Networiking Event, Nice, France, June 2016	TID

Table 8 lists the workshops organized or sponsored in Year 1. A total of 7 workshops have been organized, at the approx. average rate of 1 workshop every 2 months.

Table 8: Workshops organized or sponsored.

#	Month	Workshop	Country
1	May'16	"IEEE ICC 2016 2nd Workshop Next Generation Backhaul/Fronthaul Networks", in conjunction with IEEE ICC'2016	Malaysia
2	Jun'16	"Workshop on Software Defined 5G Networks (Soft5G 2016)", in conjunction with 2nd IEEE Conference on Network Softwarization – NetSoft 2016.	South Korea
3	Jul'16	"OSOMI 2016 workshop On-the-fly services in on-the-fly mobile infrastructures"	Germany
4	Jun'16	1st International Workshop on Elastic Networks Design and Optimisation (ELASTICNETS 2016)	Spain
5	Jun'16	"Workshop Next Generation fronthaul/backhaul integrated transport networks", in conjunction with EUCNC 2016	Greece
6	Jun'16	"Workshop Towards Converged X-Haul for 5G Networks", in conjunction with EUCNC 2016	Greece
7	Jun'16	"Workshop Network Function Virtualization (NFV) and Programmable Software Networks", in conjunction with EUCNC 2016	Greece

Table 9 lists the demonstration activities exhibited by the project in Year 1. A total of 12 demonstrations were exhibited including 4 noticeably at the flagship event of Mobile World Congress 2016.

Table 9: Demonstrations exhibited.

#	Month	Description	Leading Partners
1	Oct'15	Demonstration of 5G-Crosshaul research on orchestration at the 5G-PPP booth during ICT2015, Lisbon, Portugal.	CTTC
2	Oct'15	Wireless SDN proof of Concept demonstration with leading partners at 5TONIC, Madrid, Spain.	UC3M, NEC, TID
3	Dec'15	Video demonstration jointly between 5G-Crosshaul and FP7 iJOIN at Globecom, San Diego, USA.	UC3M IDCC
4	Feb'16	MWC'16 demonstration EdgeHaul Millimeter Wave Gigabit Transport featuring a Telepresence 5G Application.	IDCC
5	Feb'16	MWC'16 demonstration Hierarchical SDN Orchestration of Wireless and Optical Networks	CTTC
6	Feb'16	MWC'16 demonstration OpenEPC 7	CND
7	Feb'16	MWC'16 demonstration mmWave backhaul	HHI
8	Apr'16	2nd ONF PoC on SDN for Mobile Wireless,	TID, NEC
9	Jun'16	EUCNC'16 demonstration Fronthaul Compression, Athens, Greece	EAB
10	Jun'16	EUCNC'16 demonstration RRU/BBU functional split with an Ethernet-based fronthaul, Athens, Greece	CND
11	Jun'16	EUCNC'16 demonstration Optical Wireless Link: Low-cost short-range optical backhaul, Athens, Greece	HHI
12	Jun'16	EUCNC'16 video demonstration of High Speed Train Testbed in Taiwan, Athens, Greece	ITRI

3.2.2 Collaboration Activities

5G-Crosshaul has been active in 5G-PPP cross-projects collaboration activities, including the CSA working groups, METIS-II initiative on use cases and performance evaluation, and joint workshops. A summary of the activities is provided below.

3.2.2.1 Participation in 5G-PPP CSA working groups

Vision & Societal Perspective: TI is the lead representative of 5G-Crosshaul in this working group. The activities undertaken in Year 1 include:

- Contribution input to "5G and Media & Entertainment" white paper.
- Contribution input to the definition of Key messages for MWC 2016.
- Input to 2016-2017 5G PPP Work Program and ongoing definition of experimentation strategies and Phase 3 scoping paper.
- Contribution to White Papers on automotive, FoF, energy and e-health, and White Paper on media and entertainment.
- Regular participation in the conference calls.

Architecture: NEC is the lead representative of 5G-Crosshaul in this working group. The activities undertaken in Year 1 include:

- Contribution to the white paper "View on 5G Architecture" published in June 2016.

- Contributions to joint White Paper, in coordination with 5G-Xhaul, under preparation.
- Contribution input to the definition of Key messages for MWC 2016.
- Presentation "An introduction to 5G-Crosshaul" at WG call.
- Presentation "5G-Crosshaul system architecture" at WG call.
- Triggered possibility for cross-project workshops on architecture, with 5G-NORMA and 5G-Ex.
- Contribution input to the Terms of Reference.
- Attendance to two face to face meetings planned in addition to regular participation in the conference calls.

Pre-standards: IDCC is the lead representative of 5G-Crosshaul in this working group. The activities undertaken in Year 1 include:

- Support for the WG call for active participation in the ETSI workshop on 5G from research to standards – Presented the standardization roadmap for 5G integrated fronthaul and backhaul at the Workshop in 2016.
- Supported the WG proposal for EUCNC 2016 standardization workshop and serving in the TPC.
- Input report on the IEEE pre-industrial workshop on Mobile Edge, New Jersey, USA, November 2015.
- Input contribution to the 5G-PPP presentation at the 3GPP 5G RAN workshop in Phoenix, USA, September 2015.
- Regular participation in the conference calls.

Spectrum: UC3M is the lead representative of 5G-Crosshaul in this working group. The activities undertaken in Year 1 include:

- Input contribution to the Terms of Reference (document pending approval).
- Input contribution to the 5G-PPP presentation at the international workshop on standards and spectrum cooperation, Lisbon, ICT 2015.
- Attendance of all meetings (calls and face-to-face meeting in April 25th, in Brussels).

Software Networks: NOK-N is the lead representative of 5G-Crosshaul in this working group. The activities undertaken in Year 1 include:

- Contribution to a white paper "5G Software Networks" under preparation, with leadership of section on the relevant standardization activities.
- Supported the proposal (accepted) for half-day workshop at EUCNC in June 2016, and planning active participation including one presentation from IDCC.
- Supported the work on the questionnaire by SONATA on NFV MANO Adoption Priorities for Software Networks.
- Regular participation in the conference calls.

Network management, QoS and Security: POLITO is the lead representative of 5G-Crosshaul in this working group. The activities undertaken from July 2015 to June 2016 include:

- Supported a proposal for half-day workshop at EUCNC in June 2016.
- Editing work for a White Paper on "NFV Management in 5G networks", jointly written with other WG participants.
- Regular participation in the conference calls.

3.2.2.2 5G-PPP METIS-II use cases and performance evaluation

The METIS-II project started an initiative for consolidation of the use cases and performance evaluation methodologies across the various 5G-PPP projects. This initiative followed on the METIS-II 5G-PPP cross-projects workshop in Stockholm 28-29 September 2015. Two conference calls have been scheduled and attended by 5G-Crosshaul representatives, with a template for consolidation of the use cases. 5G-Crosshaul has already contributed with its use cases to the METIS II workshop, and will consider the relevance of the METIS II template for consolidation of all use cases across all the projects. The input contributions from 5G-Crosshaul are mainly derived from the work done in WP1 IR1.1.

3.2.2.3 Workshops and other activities

5G-Crosshaul has taken active role in supporting and participating in 5G-PPP workshops, as summarized in Table 10.

Table 10: Project participation in 5G-PPP workshops.

#	Month	Description	Leading Partners
1	Sep'15	Participation in the 5G-PPP METIS II cross-project workshop with two presentations from 5G-Crosshaul, Stockholm, Sweden.	IDCC TI
2	Nov'15	Participation in the 1st Sino-Europe 5G Technical Workshop through presentations on 5G-Crosshaul architecture and panel, hosted by the FuTURE FORUM 5G SIG and co-organized by 5G NORMA and METIS II, Beijing, China.	UC3M NEC
3	Jan'16	Participation in the 2nd 5G-PPP METIS II cross-project workshop with two presentations from 5G-Crosshaul, Valencia, Spain.	NEC IDCC
4	May'16	Contribution to the submission of a proposal for 2nd International Workshop on 5G RAN Design at Globecom 2016, jointly with METIS-II, FANTASTIC5G, mmMAGIC, and FLEX5GWARE.	NEC EAB
5	Jun'16	Contribution to the proposals of workshops at EUCNC 2016 by the 5G-PPP working groups (architecture, pre-standards, software networks, network management).	NEC IDCC NOK-N POLITO

In addition, 5G-Crosshaul has initiated discussion with the COHERENT project (through common partner CREATE-NET) to plan a joint workshop to explore the potential of synergy between the two projects. The discussion is ongoing and the outcome will be reported in the next deliverable or internal report. 5G-Crosshaul has also provided input contribution to the 5G-PPP representative participating in the DigiWorldSummit 2015 on the topic of Gigabit Era, where key messages have been pointed out to highlight 5G-Crosshaul approach to deal with the Gigabit traffic envisioned in 5G.

3.3 Work Plan for Year 2

As previously mentioned in section 3.1, the objectives set for dissemination and collaboration activities remain valid along the entire duration of the project, hence they remain applicable to Year 2. The focus in Year 2 will be put on results and trials compared to Year 1 where the focus was on project concept and initial results.

In particular for some dissemination activities, which can be measured, we aim to specify target numbers to achieve in Year 2 similar to what we have done in Year 1. These numbers in Year 2 account for the results achieved in Year 1 and for any scheduled activity in Year 2 that was prepared in Year 1 (e.g. submitted papers, scheduled talks, submitted workshop proposals, etc.). We therefore plan in Year 2 to boost the numbers targeted for talks, articles, demonstrations, and workshops such as:

- Demonstrate the project proof-of-concepts at least at 2 R&D exhibitions.
- Delivery of at least 20 talks at key R&D events.
- Publication (or acceptance for publication) of at least 20 peer-reviewed articles.
- Organization of at least 2 workshops.

4 Standardization Activities

Maximizing the impact of the project innovations on present and future standardization and industry forums has been set as a key objective in order to help create opportunities for commercial exploitation of the project outcomes. This chapter presents first the plan set in Year 1 and reports next on the activities and achievements undertaken. An outline of the plan for Year 2 is then provided.

4.1 Work Plan for Year 1

The project has set the following three objectives for the standardization activities:

1. Create and maintain a project standardization activity roadmap. This roadmap will capture the standardization activities that may influence or get influenced by the project technological innovations. It will help (i) keep track of existing or upcoming industry specifications or recommendations that might affect the project technological choices; and (ii) identify opportunities for the project to contribute its proposed solutions to present and future standardization groups.
2. Disseminate the project into the standardization forums to raise awareness and help create an opportunity for standardization exploitation.
3. Contribute through the partners (individually or jointly) with project-related technology proposals into the relevant standardization forums.

The above objectives remain applicable over the whole project duration. With focus on Year 1, it is anticipated that the activities will first involve the creation of the project standardization activity roadmap (Objective 1). As the design of the project solutions progresses, we anticipate to see more efforts spent on standardization dissemination and contributions (Objectives 2 and 3).

4.2 Standardization Activity Roadmap

In order to create the project standardization activity roadmap, we have followed the two steps below:

1) Identify the standardization activities that may be relevant to the Project.
2) Map the project technology development areas onto the standardization activities from 1) above, by accounting of the timeline towards 2020.

The above two steps are presented in the following sub-sections.

4.2.1 Relevant standardization activities

4.2.1.1 3GPP

At the 3GPP [2] 5G RAN workshop in Phoenix (USA), 17 September 2015, the need to specify in 3GPP new fronthaul interface(s) has been motivated by a number of players (such as NTT DoCoMo, Nokia Networks). This new interface will need to support different levels of functional split between the digital (or central) unit and the remote unit of the base station (eNB). In April 2016, 3GPP RAN task group has begun to draft a

technical report (TR 38.801) entitled *"TR for Study on New Radio Access Technology: Radio Access Architecture and Interface"*, which aims to capture the results of 3GPP's new study item on New Radio Access Technology. In particular, centralized baseband deployments using remote radio units connected over a high performance transport network to a centralized baseband unit, has been included in the scope. It has been agreed that 3GPP will study different functional splits for the fronthaul, with considerations of new protocol stacks that will be defined by 3GPP for New Radio. Currently, none of the possible function split options has been precluded in the study within 3GPP.

4.2.1.2 BBF

The Broadband Forum (BBF) [3] is a key organization for developing broadband packet networking specifications. Recently in 2016, the BBF has re-structured its work to focus on the following working areas, which obviously address the envisioned convergence between fronthaul and backhaul:

- Architecture and Migration Work Area
- Broadband User Services Work Area
- Fibre Access Networks Work Area
- Fibre to the Distribution Point (FTTdp) Work Area
- Physical Layer Transmission Work Area
- Routing and Transport Work Area
- SDN and NFV Work Area
- Wireline-Wireless Convergence Work Area

4.2.1.3 CPRI

The Common Public Radio Interface (CPRI™) [4] is currently the de-facto standard for fronthaul connecting the Radio Equipment to Radio Base Station. The latest public CPRI specifications provide support for high (higher than 10 Gbps) line rates. Recent liaisons between CPRI and IEEE 802.1 (TSN) and IEEE 1904.3 (RoE) indicate the movement of CPRI towards packet (Ethernet)-based fronthaul.

4.2.1.4 ETSI

At least four ETSI [5] industry specification groups (ISGs) are envisioned to impact the 5G integrated fronthaul and backhaul:

- ETSI Network Function Virtualisation (NFV), which provides normative specifications for fully virtualized network platforms as wells as plug-fests for interoperability.
- ETSI Mobile-edge Computing (MEC), which provides IT and cloud-computing capabilities within the Radio Access Network (RAN).
- ETSI millimetre Wave Transmission (mWT), which provides a platform for the use of millimetre-wave in wireless fronthaul and backhaul links.
- ETSI Open Radio Equipment Interface (ORI), which developed an interface specification for enabling interoperability between Base Band Units (BBUs) and Remote Radio Heads (RRHs) of cellular mobile network equipment.

4.2.1.5 FSAN

The Full Service Access Network (FSAN) [6] is a forum with more than 70 member organizations, including more than 20 network operators that represent the leading experts in BPON, GPON, XGPON1 and NGPON2 technologies. Two key topics in FSAN are of particular relevance to the 5G integrated fronthaul and backhaul:

- Evolution of PON technology - Technologies for the transport of existing backhaul but also fronthaul traffic.
- New recommendation "G-RoF" - A new type of optical access network based on radio-over-fiber (RoF) technologies.

4.2.1.6 IEEE

The fronthaul has received recently an increasing attention in IEEE [7] specification groups, as clearly witnessed in the IEEE 802.1 (TSN), IEEE 1904, IEEE 1914, and IEEE 802.11ay working groups.

In the IEEE 802.1 TSN, a new activity (802.1CM) has started recently with focus on the support of the fronthaul requirements in the TSN protocols. The primary goal of 802.1CM is to specify a TSN profile for conventional CPRI (i.e., the classical split between RF and Baseband). The CPRI requirements are being provided by CPRI Cooperation. However, 802.1CM remains open to specify a profile for another functional split (compared to CPRI) if the requirements are provided and agreed.

In parallel, the IEEE 1904.3 RoE group is getting close to finalizing its specification document. However, the specification is restricted to CPRI and CPRI-like traffic (i.e., does not include new functional splits). To expand beyond the conventional CPRI and CPRI-like traffic, a new group IEEE 1914.1 has been recently created targeting a new specification for packet-based fronthaul transport networks. The scope of this new group includes the specification of:

- Architecture for the transport of mobile fronthaul traffic (e.g., Ethernet-based), user data traffic, and management and control plane traffic.
- Requirements and definitions for the fronthaul link, including data rates, timing and synchronization, and quality of service.

The standard will also define functional partitioning schemes between Remote Radio Units (RRUs) and Base-Band Units (BBUs) that improve fronthaul link efficiency and interoperability among various vendors, and that facilitate the realization of cooperative radio functions. Liaisons have recently been exchanged between IEEE 1914.1 and the 3GPP for cooperation on the specification of the next generation fronthaul interface.

4.2.1.7 IETF/IRTF

The Internet Engineering Task Force (IETF) [8] has recently established the DetNet (Deterministic Networking) working group, with focus on solutions for deterministic data paths that operate over Layer 2 bridged and Layer 3 routed segments, where such paths can provide bounds on latency, loss, and packet delay variation (jitter), and high reliability. One key example application for deterministic networks is the transport of

fronthaul traffic with deterministic forwarding requirements in packet switching networks. The Working Group focused on Layer 3 protocols collaborates with IEEE 802.1 TSN, which is focused on Layer 2 operations, so that together they define a common architecture covering both Layer 2 and Layer 3 for the fronthaul transport.

In addition, the IRTF has two active research groups on SDN and NFV, SDNRG and NFVRG, respectively, which are particularly relevant for the control and virtualization of the 5G fronthaul and backhaul.

4.2.1.8 ITU

ITU-R Working Party (WP) 5D set its "Vision" of the "5G" mobile broadband connected society in 2015. The group is now focused on defining in detail the performance requirements, evaluation criteria and methodology for the assessment of new IMT radio interface, in anticipation for proposals in 2018. These requirements will need to be accounted for in the design of the 5G fronthaul and backhaul. Moreover, activities of particular relevance to the 5G fronthaul and backhaul are carried out at the ITU-T Study Group 15, Questions 6 and 11, and in the Focus Group IMT2020 [9].

- Recommendation G.metro: ITU-T SG15 Q6 is currently developing a recommendation G.metro, where WDM-based transport solution is defined for metro applications. CPRI (or similar) fronthaul interfaces can be transported over metro WDM system.
- CPRI over OTN: ITU-T SG15 Q11 addresses signal structures, interfaces, equipment functions, and interworking for optical transport networks. CPRI over OTN is a key topic and it was agreed in 2016 to include CPRI Option 10 (25G bit rate).
- IMT2020 Focus Group: The IMT2020 Management Team released a report in 2015 on standards gap analysis. This report included gaps for future transport networks with special attention on the fronthaul where the key gaps are identified. Since then, the focus group has been active in 2016 developing recommendations for future specification work including fronthaul and backhaul slicing. Future work is anticipated to take place in ITU-T SG13 and in collaboration with other forums active in this space (e.g. IEEE, ETSI, and NGMN).

4.2.1.9 NGMN

The NGMN [10] (Next Generation Mobile Networks) Alliance has recently developed end-to-end operator requirements to satisfy the needs of customers and markets in 2020 and beyond, published in the NGMN 5G White Paper in 2015. This was followed recently by the launch of NGMN 5G-focused work programme that will build on and further evolve the White Paper guidelines with the intention to support the standardisation and subsequent availability of 5G for 2020 and beyond. The work programme included a project focused on "Requirements & Architecture". The project work streams will define technical requirements for enhanced mobile broadband services, vertical industries and 5G security. Additionally it will consider end-to-end architecture design principles and recommendations for the management and orchestration of 5G networks. The results will be delivered to all major SDOs, to the ITU and other 5G related organisations.

Furthermore, NGMN concluded in 2014 two activities of relevance to future transport network, namely, the RAN Evolution Project and the Small Cells Project. Both activities indicated operators' requirements on fronthaul and backhaul evolution. In particular, the RAN Evolution Project defined also a radio architecture to provide base band pooling and distributed/centralised RAN.

4.2.1.10 ONF

Open Networking Foundation (ONF) [11] is a user-driven organisation dedicated to the promotion and adoption of Software-Defined Networking (SDN) through open standards development. Its signature accomplishment to date is introducing the OpenFlow standard, which enables remote programming of the forwarding plane. ONF maintains several working groups including the following key groups of particular relevance to the future SDN-based integrated fronthaul and backhaul:

- The Optical Working Group (OTWG) addresses SDN and OpenFlow Standard-based control capabilities for optical transport networks.
- The Wireless & Mobile Working Group (WMWG) is chartered to collect use cases and determine architectural and protocol requirements for extending ONF based technologies to wireless and mobile domains.
- The Configuration and Management Working Group (CMWG) addresses a series of core Operations, Administration, and Management (OAM) issues.
- The Architecture Project (ArchPG) seeks to understand how SDN principles apply across the entire problem space (telecommunications and cloud).
- The Layer 4-7 Services Working Group focuses on end-to-end services that require various L4-L7 functions and chaining, including how OpenFlow protocols are used for forwarding nodes, virtualized network functions, and methods to interact with orchestration layer.
- The Carrier Grade SDN Working Group focuses on the unique needs of carrier operators for SDN environments.

4.2.1.11 Photonics21

The European Technology Platform (ETP) Photonics21 [12] unites the majority of the leading photonics industries and relevant R&D stakeholders along the whole economic value chain throughout Europe. Photonics21 aims to establish Europe as a leader in the development and deployment of photonics technologies within the various applications fields such as ICT, lighting, industrial manufacturing, life science, safety as well as in education and training. Participants of the Photonics21 WG1 (ICT) are contributing to the optical networking areas in the 5G-PPP phase 2 pre-structuring proposal. The areas of the proposals relevant to 5G-Crosshaul that received inputs from Photonics21 are:

- TA8: Cost-efficient Optical Metro Networks for 5G Backhaul – Define a new data plane for the optical metro, backhaul and aggregation network segment (network and node architecture, system design and transmission dimensions).
- TA18: Ubiquitous 5G Access Leveraging Optical Technologies – The objectives of TA18 include i) to conceive efficient hardware for new optical access networks for 5G mobile fronthaul; ii) to design a unified control architecture of a converged

5G system covering heterogeneous radio, optical access, and optical fronthaul technologies in tandem; iii) to enable a dynamic and coordinated radio and optical network resource management; and iv) to facilitate a tight optics-wireless integration at equipment, link and network level.

4.2.1.12 SCF

Small Cell Forum (SCF) [13] mission is to drive the wide-scale adoption of small cells and accelerate the delivery of integrated HetNets. In 2015, the SCF carried out several activities focused on small cell virtualization and published various related documents such as:

- SCF154 Virtualization in small cell networks
- SCF155 Backhaul for rural and remote small cells
- SCF159 Small cell virtualization functional splits and use cases
- SCF160 Coverage and capacity impacts of virtualization
- SCF161 Network aspects of virtualized small cells

4.2.2 Classification and mapping of standardization activities

Based on the standardization activities identified above, a classification of the standardization activities per technology development area (or topic) in the project is first attempted. This is shown in Table 11.

Table 11: Classification of standardization activities for 5G fronthaul and backhaul.

No.	Technology development area in the project	Standardization groups
1	Use cases, gaps, requirements, architectures	NGMN, ITU-T 2020 FG, ITU-R WP5D, 3GPP, BBF, SCF
2	Gbps transmission technology (wired/wireless)	Wired: ITU-T SG15, NG-PON2, 100GE, CPRI Wireless: ETSI mWT, IEEE 802.11ay
3	Wireless access protocol functional splits	3GPP, IEEE 802.11, IEEE 1914.1, SCF
4	Fronthaul and backhaul traffic packetization (formatting)	Fronthaul: CPRI, NGFI (IEEE 1914.1 inc. 1904.3) Backhaul: VLAN (IEEE 802.1Q), MPLS

5	Fronthaul and backhaul traffic forwarding (switching protocols)	IEEE 802.1CM (Time Sensitive Networking), IETF DETNET (Deterministic Networking)
6	SDN control	ONF (OpenFlow), OpenDayLight, ONOS, IRTF SDNRG, ITU-T SG13, IEEE 802.1CF
7	NFV-based management and orchestration	ETSI NFV, IRTF NFVRG, OPNFV, OpenMANO, OpenStack, ETSI MEC

A standardization roadmap is then depicted in Figure 2 with an indicative timeline towards the year 2020.

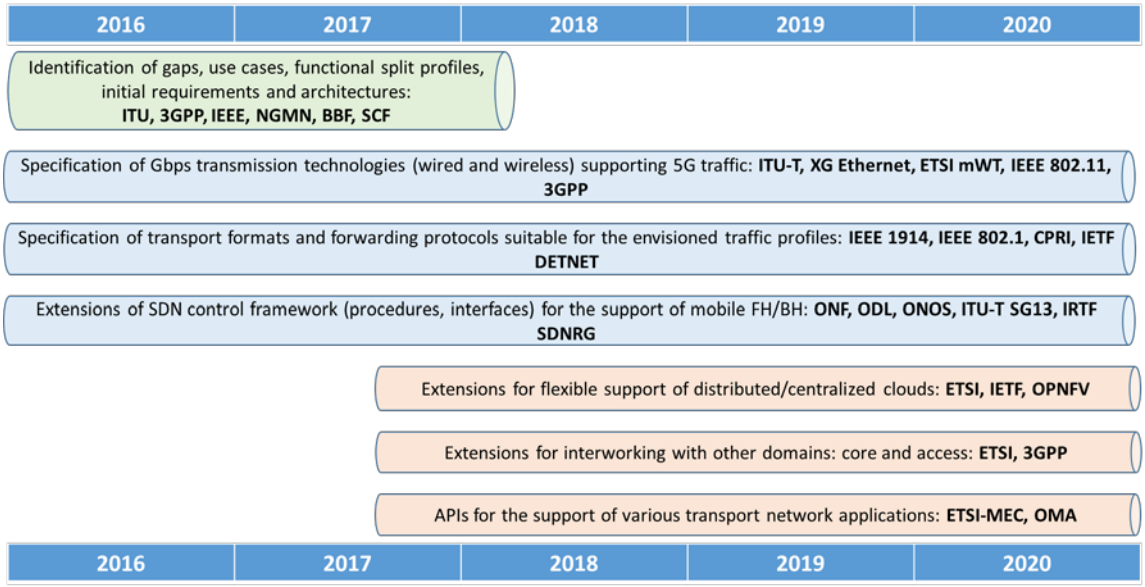

Figure 2: Initial standardization activity roadmap towards 2020.

As shown, the 2016 and 2017 time frame will continue to see the identification of gaps, definition of functional split profiles for the fronthaul, as well as requirements and architectures. The key SDOs involved here are: ITU (T/R), 3GPP, IEEE, NGMN, BBF and SCF.

In parallel, the specification of Gbps transmission technologies both wired and wireless for fronthaul and backhaul is anticipated to continue until 2020 and beyond. These are taking place in ITU-T, 100G-Ethernet, ETSI mWT, IEEE 802.11 (ax, ay), and 3GPP.

The transport formats and forwarding protocols are also underway in several groups such as IEEE 1914.1, CPRI, IEEE 802.1CM, IETF DetNet, and these are anticipated to continue until 2020.

Now on the SDN-based control plane, several activities are ongoing in forums such as ONF, ONOS, ODL, ITU-T, IETF/IRTF, including extensions for support of wireless and wired transport. These are anticipated to continue until 2020.

Further ahead, standardization related to areas for extensions of the integrated fronthaul and backhaul framework to cover emerging aspects such as edge cloud, fog computing, cross-domain orchestration (across core, transport and access), as well network applications for running on top, is envisioned to start in the timeframe of 2017/2018, and continue until 2020 and after.

The ITU-T 2020 Focus Group is developing recommendations for identified standardization gaps in the area of mobile fronthaul and backhaul slicing. These recommendations are due end of 2016, and are expected to feed into the work plan of specification groups inside ITU-T but also external organizations such as ETSI, 3GPP, IEEE, and IETF.

It is also worth noting that an interest has been identified at ETSI to consider an initiative for providing a standardization framework for what is commonly referred as *xhauling*. This followed a presentation in May 2016 by the 5G-Crosshaul project on its standardization activity roadmap. As next step, ETSI is gathering interest from member organizations on 4 technical areas including *xhauling* where ETSI intends to develop first white papers steered towards identifying standardization gaps that ETSI can address. This is being monitored and contributed to by the 5G-Crosshaul project.

4.3 Standardization Dissemination and Contribution

In addition to the creation of its initial standardization roadmap, the 5G-Crosshaul partners have undertaken activities to disseminate the project concept and initial results at various standardization forums. Table 12 reports on these standardization dissemination activities in Year 1.

Table 12: Standardization dissemination in Year 1.

#	Month	SDO	Description	Leading Partner
1	Oct'15	ONF	White Paper on Wireless Transport SDN Proof of Concept, 09 October 2015, ONF website.	TI, NEC, EAB, UC3M
2	Oct'15	FSAN	Presentation on "Mobile evolution and impact on optical access network, at the FSAN workshop, October 2015, Atlanta, USA.	ORANGE
3	Oct'15	BBF	Presentation on "Assessing the Evolution of Cloud RAN with the Support of Fibre", BroadBand World Forum, 22-25 October 2015, London, UK.	ORANGE
4	Nov'15	IEEE	Presentation on "NEC Vision and R&D activities towards 5G" at IEEE 5G Summit, Toronto, Canada, 14. November 2015.	NEC

5	Nov'15	3GPP	Presentation promoting 5G-Crosshaul concept at the 3GPP Asia summit in Taipei, 15 November 2015.	ITRI
6	Nov'15	IEEE	Presentation on 5G-Crosshaul architecture and research related to Mobile Edge Cloud at the IEEE pre-industrial workshop on Mobile Edge Cloud, New Jersey (USA), 16 November 2015.	IDCC
7	Nov'15	BBF	Presentation in BBF 5G BoF Session on "Small Cell Forum & Mobile Edge Computing", Broadband Forum, 16 November 2015.	NEC
8	Dec'15	NGMN	Presentation "5G Technologies: An introduction", NGMN IPR Forum workshop on 5G Technologies, Vienna, Austria, 11 December 2015.	IDCC
9	Mar'16	ETSI	Presentation of 5G-Crosshaul, ETSI MEC ISG #17 meeting, Madrid, Spain, 17 March 2016.	Telefonica
10	Mar'16	NGMN	Presentation "5G-Crosshaul Project Overview", NGMN Forum Meeting, Taipei, Taiwan, 15 March 2016.	IDCC
11	Apr'16	ETSI	Poster "5G-Crosshaul project" at ETSI workshop (5G from myth to reality), Sophia-Antipolis, France, April 2016.	IDCC
12	May'16	ITU-T	Presentation "Introduction to the 5G-Crosshaul project" at ITU-T meeting, Beijing, China.	IDCC
13	May'16	ETSI	Presentation "Standardization Roadmap for the 5G Intergrated Fronthaul and Backhaul" at ETSI workshop (5G from research to standardization), Sophia-Antipolis, France, May 2016.	IDCC
14	May'16	ONF	Contribution to the Technical Recommendation TR-528 "Mapping Cross Stratum Orchestration (CSO) to the SDN Architecture".	CTTC

In addition to the dissemination activities above, the partners have submitted input contributions to standardization working groups, as summarized in Table 13 below.

Table 13: Standardization contributions in Year 1.

#	Month	SDO	Description	Leading Partner
1	Oct'15	ITU-T Q6/15	Contribution (WD06-32) by the G.metro Editors, "Version 0.3 of draft new Recommendation G.metro generated at the last SG15 Plenary Meeting in Geneva June/July 2015".	TEI
2	Oct'15	ITU-T Q6/15	Contribution (WD06-31) by the G.metro Editors in their role as correspondence group coordinators, "Results of correspondence on draft G.metro issues carried out since the last SG15 Plenary Meeting in Geneva June/July 2015".	TEI

3	Oct'15	ITU-T Q6/15	Contribution (WD06-37), "Results of the break-out group meeting to establish the terms of reference for a correspondence activity to establish a set of requirements for pilot tone frequency and message channel bit rate, traffic signals and their characteristics that should be taken into consideration for the development of application codes in G.metro".	TEI
4	Oct'15	ITU-T Q6/15	Contribution "Information to Q6/15 on proposals towards Q11/15 and Q14/15 for the communications channel in G.metro".	TEI
5	Oct'15	ITU-T Q6/15	Contribution "Provisional results from an editing session on G.metro".	TEI
6	Nov'15	IEEE 802.11ay	Contribution (IEEE 802.11-15/1399r1), "11ay Functional Requirements for Multi-Hop, Backhaul, and Fronthaul", 09 November 2015.	IDCC
7	Dec'15	IMT2020 FG	Contribution to IMT-2020 Focus Group final report, planned to discuss this report and the way forward during SG13 plenary meeting on 7 December 2015.	TEI
8	Dec'15	IRTF NFVRG	G. Bernini, V. Maffione, D. Lopez, P. Aranda Gutierrez, "VNF Pool Orchestration for Automated Resiliency in Service Chains", NFVRG Interim meeting, December 2015.	NXW TID
9	Feb'16	BBF	X. Li, K. Samdanis, "5G fronthaul and Base Station functional split"	NEC
10	Mar'16	ETSI MEC	Contribution (MECIEG(16)000016), "Changes to MEC Metrics: delay and footprint" at ETSI MECIEG#17, Madrid, Spain.	UC3M NEC TIM
11	Mar'16	ETSI MEC	Contribution (MECIEG(16)000017), "Measurement methodologies for energy and delay" at ETSI MECIEG#17, Madrid, Spain.	UC3M TIM NEC
12	Mar'16	ETSI MEC	Contribution (MECIEG(16)000020r1), "Changes to MEC Metrics: delay" at ETSI MECIEG#17, Madrid, Spain.	UC3M NEC TIM
13	Mar'16	ETSI MEC	Contribution (MECIEG(16)000022r1), "Changes to MEC Metrics: footprint" at ETSI MECIEG#17, Madrid, Spain.	UC3M NEC TIM
14	April'16	BBF	X. Li, K. Samdanis, A. Garcia-Saavedra, "On base station functional decomposition and fronthaul performance requirements"	NEC
15	May'16	IMT2020 FG	Contribution (I-206) "Introduction of 5G-Crosshaul project" including proposed text for adoption in the recommendations, at ITU-T 2020 FG, Beijing, China.	IDCC

4.4 Work Plan for Year 2

The objectives set in section 4.1 remain applicable over the whole project duration, hence applicable to Year 2. Specifically in Year 2, we see the following:

- For the standardization roadmap, as we have already set an initial roadmap in Year 1, the focus in Year 2 will be on maintaining this roadmap with updates as new groups emerge, and others draw to a close. In addition to these updates to the roadmap, the 5G-Crosshaul project shall continue to closely follow the relevant standardization activities, so that it can account for new requirements, architectures, and technologies as they emerge from the standardization forums, in the development of the 5G-Crosshaul solution.
- For the dissemination, like in Year 1, we shall strive in Year 2 for a continuous dissemination in standardization forums with the aim to raise awareness of the project technology, and at the same time, receive feedback from the standardization community on our technology development plan and how best we can steer it towards successful transfer into standards.
- For the input contributions, anticipating that the technology under development by 5G-Crosshaul will mature in Year 2 as planned, we plan to generate more input contributions on technology proposals coming out of the 5G-Crosshaul project and championed by the 5G-Crosshaul partners. We are not setting a specific target number of input contributions here, as it is not possible to have such a commitment. But we do hope that opportunities will arise in Year 2 for more input contributions relating to the 5G-Crosshaul technology development area.

5 Exploitation Activities

It is the project's ultimate goal to achieve tangible exploitation of its findings and results during the course of the project and afterwards. Various forms of exploitation are targeted including pre-commercial proof-of-concepts and commercial products, innovations and new features adopted into standards, and new services. Whilst Chapter 4 presented on the standardization activities, this chapter sets focus on the proof-of-concepts and products as well as potential new services which might feature innovations from the project. This chapter presents first the work plan set for exploitation activities in Year 1. It moves next to describe proof-of-concepts and products as well as new services which are identified with potential impact from/to the project. The key innovations identified in Year 1 are then summarized, followed by an insight on the activities foreseen in Year 2.

5.1 Work Plan for Year 1

The work plan set in Year 1 was centred on the development of an initial strategy for exploitation activities. Such a strategy is envisioned to:

- Identify products and services which might bear a potential impact from/to the innovations targeted by the Project;
- Identify innovations as they emerge from the technology development undertaken by the technical work packages (WP1/2/3/4/5);
- Map these innovations onto identified products and services of industrial stakeholders, and;
- Promote the exploitation of these innovations by the various stakeholders.

In view of the high importance given by the project to the exploitation activities, the project has appointed an Innovation Manager (Dr Paola Iovanna from Ericsson Italy) to lead the work and ensure successful exploitation of the innovations from the project.

5.2 Activities Related to Commercial Exploitation in the Form of PoCs, Products and Services

A first step in the exploitation strategy is to identify the pre-commercial proof-of-concepts, commercial products, and services, from the project partners, which might have an impact from/to the innovations targeted by the project. This is done in this section with focus on the PoCs, products and services the project has identified in Year 1.

5.2.1 Proof-of-Concepts

5.2.1.1 Wireless SDN transport PoC

Four partners (TID, NEC, EAB, UC3M) from 5G-Crosshaul participated together with other industry players in the demonstration of the wireless SDN transport proof of concept in Madrid in October 2015. Telefonica and IMDEA Networks as a 5TONIC (www.5tonic.org) activity, hosted together the PoC. Six vendors (in alphabetical order) namely Ceragon, Coriant, Ericsson, Huawei, NEC and SIAE participated in the tests, providing, with the support of the Universidad Carlos III de Madrid, a variety of types of equipment and software consistent with the SDN architecture, leveraging ONOS as controller. The PoC has shown the implementation of the OpenFlow [14] wireless transport extension defined in the context of ONF by wireless transport project under

OTWG. It has been demonstrated the interoperability among five wireless transport vendor products and a switch product, implementing the same extensions, in an open environment with an ONOS based controller. The demonstrated applications have shown how programmability at the network level and on top of the SDN Controller for managing a wireless transport network can provide a significant contribution to network OPEX reduction.

5.2.1.2 CoreNetworkDynamics OpenEPC and eNodeB PoCs

CoreNetworkDynamics (CND) reported further development of its OpenEPC solution towards its v7 release targeted for 2016. The scope of OpenEPC v7 supports the company mission of commercial deployments for targeted use cases: public safety, NFV/SDN and IoT. In the area of NFV/SDN, two elements have been identified as relevant to the product: compatibility with the OPNFV environment and NFV deployments in containers. While these two items are not directly addressed in the project, the work done for the release v7 will contribute to a better understanding of the advantage for OpenEPC to integrate into a framework like OPNFV that includes both SDN Control layer elements and NFV infrastructure, such as in 5G-Crosshaul.

CND OpenEPC provides the possibility to connect Small Cells to the Core Network. Thanks to its flexibility, OpenEPC can be adapted to the new concepts that will be developed within 5G Crosshaul to backhaul the Small Cells into the Core Network. CND has been developing its eNodeB prototype implementation towards supporting the 5G-CrossHaul architecture. Current target is an LTE capable eNodeB based on a software defined radio board from a third party. After having a functional eNodeB, a C-RAN implementation with split functionality and flexible fronthaul shall follow. This is fully aligned with the 5G-Crosshaul agenda to support flexible fronthaul functional split. It is planned that CND prototypes will take part of the integrated demonstration in Berlin in Q4'2016, with other partners such as InterDigital and Fraunhofer HHI. Joint pre-integration work is already underway.

5.2.1.3 Ericsson optical forwarding nodes

Ericsson Italy (TEI) has started defining new data-plane solutions for 5G-Crosshaul based on multi-layer technology that makes use of suitable circuit base switching and optical technology. Actually it has started the investigation of frontier optical technology that can meet tight requirements of low latency and low cost required in the 5G-Crosshaul scenario. Product feasibility studies and prototyping activities are ongoing, fully in line with WP5 plans.

5.2.1.4 InterDigital Small Cells Mesh Millimetre Wave Backhaul

InterDigital's EdgeHaul™ [15] system is a small cell wireless mesh backhaul system built on EdgeLinks which are 60 GHz millimetre wave links that can deliver multi-gigabit-per-second speeds with low latency. It provides Gbps throughput to densely deployed small cells with a potential link range of hundreds of meters. The flexible antenna steering enables multi-hop and mesh topologies to be easily formed without the added cost of extra radios for each link. An SDN-based architecture, with a centralized Network Controller that is easily virtualized in the cloud, provides network management, controls data routing, and maintains data path redundancy to ensure topology resiliency. The PoC

provides operators with a low-cost Gigabit-Ethernet wireless connection to support "LTE-ready" carrier-grade high capacity small cell backhaul using spectrum which is free in many markets.

InterDigital EdgeHaul™ will take part of the demonstration scenarios and trials planned in 5G-Crosshaul. A first joint demonstration is planned with partners CND and Fraunhofer HHI in Berlin in Q4'2016.

5.2.1.5 Nextworks SDN/NFV PoC

Nextworks (NXW) plans to work, through 5G Crosshaul, on a set of SDN and NFV control and orchestration tools to enable liquid fronthaul/backhaul network topology and resources. To this purpose, it is key to move and automatically reconfigure "softwarized" network functions across the 5G network.

NXW has been working on virtual network function (VNF) pool mechanisms, Service Function Chaining modules and energy management/optimization policies for VNFs, specifically targeting the following set of features:

- Seamless and convergent control and orchestration of VNFs;
- Virtual network slice creation service;
- Virtual network and flow re-planning in multi-layer/multi-technology environments;
- SDN-based monitoring for SLA verification (OF domain metering, OF statistics, Openstack Ceilometer plus OpenDaylight);
- Signalling protocols for distributed (virtual) resource reservation and service provisioning based on the SFC concept;
- QoS configuration (meters/queues) at all levels of the SDN control, from top orchestrator layer down to virtual resources control;
- Multi-domain flow routing e.g. based on Path Computation Engines, also interoperating with legacy core/backbone domains;
- Bandwidth on demand interfaces for the backhaul and core network;
- SDN-enabled energy management, e.g. through IETF EMAN models and policies.

These functions and tools for SDN/NFV control of 5G Crosshaul network will be implemented in WP3 and will converge in a PoC of control workflows and capabilities, with focus on multi-tenancy and virtual software functions in MEC scenarios.

It is planned to build these tools on top of existing SDN/NFV open source tools (OpenStack, OpenDaylight, OpenMANO, etc.), possibly converging in mainstream platform building efforts like OPNFV.

5.2.2 Commercial Products

5.2.2.1 Ericsson Router 6000 family and Fronthaul 6000 solution

Two Ericsson IP Transport Network products are anticipated with potential impact from 5G-Crosshaul, namely: Router 6000 family and Fronthaul 6000 solution.

Ericsson Router 6000 Series is a radio integrated IP transport portfolio, managed by a single end-to-end management system, enabled by service provider SDN. It delivers high performance LTE, LTE-Advanced, 5G, Fixed Mobile Convergence and Enterprise applications. The Router 6000 Series comprises a set of versatile routers offering high capacities, resiliency features, and form factors for the diverse and challenging demands of a modern metro and backhaul network. The Ericsson router can act as fixed and mobile backhaul router, digital unit aggregation router for macro cells, indoor small cell aggregation routers, baseband hotel site router, supporting highly centralized baseband processing. Ericsson Router 6274 is a high performance, modular aggregation router designed for RAN and fixed/mobile converged metro aggregation. It provides the next level of aggregation upstream for the Routers 6672 and 6675. Combined with Ericsson radio and microwave product platforms, Ericsson Router 6000 series provides an integrated solution for high capacity mobile backhaul.

Ericsson Fronthaul 6000 enables centralized RAN architectures with low latency CPRI transport between centralized baseband units and remote radio units and accurate coordination of remote radios for optimal spectrum utilization. Within the Fronthaul 6000 product family, PAU 6000 [16] provides managed linear and protected ring DWDM networking of baseband radio transmission over a distance of 15 km. Its low-latency and high capacity networking of up to 48 managed optical channels enables the centralization of Macro cells for C-RAN architectures. Along with the Ericsson Radio System R503 Baseband CPRI multiplexer, PAU6000 provides further CPRI transport efficiency for C-RAN fronthaul transport of up to 192 remote radios. It supports CPRI, OBSAI and Ethernet services. PAU 6000 is integrated with RBS 6000 systems and cabinets and follows the same practices of outdoor and indoor operation.

5.2.2.2 Ericsson Radio Dot System

Ericsson Radio Dot system (RDS) [17] is an innovative indoor radio solution to meet high capacity traffic demand indoors, such as in shopping malls, office buildings, airports etc. It improves the cost-effectiveness via using Ethernet cables to distribute radio signals and also the power remotely, and the sleek design of the radio dot for easier installation.

The 5G Crosshaul concept with a new data plane for integrated fronthaul and backhaul will further enhance the Fronthaul transport interface design for RDS, for example CPRI fronthaul over Ethernet. More advanced features are also expected to be supported, such as multi-operator, flexible cell, etc.

5.2.2.3 Ericsson Network Manager

Ericsson Network Manager [18] provides a complete end-to-end network configuration for both mobile and fixed deployments, encompassing radio, metro and backhaul, mobile core, and data centre. This enables seamless plug and play capabilities for radio and router installation and network operation.

5.2.2.4 Ericsson Cloud System

Ericsson Cloud System eliminates complexity from IT with a unified architecture that meets performance and delivery requirements irrespective of environments. It provides security and high-performance for business-critical applications so that they work across all aspects of governance—performance, scale, quality, economics, compliance and security.

5.2.2.5 Ericsson Services SDN

Services SDN is an Ericsson product that enables end-user service personalization and deployment of massively scalable Virtualized Network Functions (VNF).

5.2.2.6 NEC iPASOLINK

NEC's Intelligent Converged Platform is designed to meet the capacity, topology, flexibility and intelligence requirements of next-generation mobile backhaul. At the core of the Intelligent Converged Platform is iPASOLINK [19], the Converged Packet Radio.

iPASOLINK is a modular network element that integrates a comprehensive set of TDM cross-connect switching, packet switching and microwave and optical features. iPASOLINK covers mobile backhaul requirements all the way from the access tail links through to the metro aggregation network employing the IEEE 1588v2 PTP standard to provide a tight synchronization between all the network elements.

iPASOLINK100A/200A/400A is the latest addition to the iPASOLINK Series of radios that builds on the existing features of the iPASOLINK 400. This new radio supports up to 2048QAM high modulation capability with comparatively lower power consumption with second generation 2048QAM modem chip set.

iPASOLINK EX is an all-outdoor, advanced IP Radio capable of delivering over 1600 Mbps of traffic per link in the 80 GHz Band. It provides a critical tool for 4G (LTE and WiMAX) deployments and LTE small cell aggregation.

A unified control plane for backhaul and fronthaul network units, like the one within the scope of 5G Crosshaul, developed within NEC´s Intelligent Converged Platform and based on iPASOLINK, will have a major impact on lowering product maintenance costs and increasing its flexibility.

5.2.2.7 NEC vEPC

vEPC [20] is a mobile-core network system that accommodates LTE access systems. Powered by NEC's carrier-grade virtualization platform and SDN technology, vEPC optimizes mobile operators' TCO and service quality.

5.2.2.8 NEC ProgrammableFlow

ProgrammableFlow [21] uses NEC's OpenFlow technology to deliver a flattened, open networking topology that simplifies network management, proactively addresses performance and contributes to high availability of mission-critical business processes. This family consists of ProgrammableFlow Controller, management console, and a series of programmable switches that can integrate into a legacy environment or a fully functional OpenFlow environment. The ProgrammableFlow Controller leverages

network virtualization and SDN techniques to help deploy, monitor, control and manage multi-tenant network infrastructure from a central point.

5.2.2.9 Nokia Flexi Multiradio 10 Base Station

Nokia expects an increasing network heterogeneity coming from 5G, along with the demand for an easier and programmable approach to network configuration. To deal with this heterogeneity, Nokia Networks product offer includes FlexiZone, Smart Wi-Fi, Femtocell Solution, Flexi Lite Base Station and Services for HetNets [22].

The outcomes of 5G-Crosshaul will be used to extend the deployment of the hybrid network and enhance its management capabilities, as 5G Crosshaul provides a common data plane for fronthaul and backhaul traffic. The energy efficiency could be increased by using algorithms and dynamic reconfiguration approaches defined in 5G Crosshaul. Further information from 5G-Crosshaul, derived from CPRI and 5G ultra-low latency applications, are expected to have an impact on timing requirements.

5.2.2.10 Nokia HetNet

5G-Crosshaul's outcomes will be considered in Nokia's Heterogeneous Networks (HetNet) solution [23]. HetNet deploys a mix of technologies, frequencies, cell sizes and network architectures to optimally respond to rapid changes in customer demand, for both LTE-A and forthcoming 5G. It helps to manage this hybrid network as a unified whole so that customers can be steered to the best cell for their speed, application and device. HetNet saves power by switching off layers at times of low traffic, reduces cost by organizing itself without intervention and maximizes efficiency by managing interference and power levels automatically.

5.2.3 Services

5G-Crosshaul goes one step further towards the "softwarization" of the telecom sector with virtualization and cloud technologies. This approach is very disruptive to today's telecom value chain, decoupling dependencies with underlying network hardware and focusing on software stacks. Not only will the applications see a network that reacts to their needs, but business scenarios become increasingly complex when actors such as infrastructure providers, software providers, system integrators and network operators need to cooperate in order for the end user to take advantage of services that perform better or of new services not achievable before. 5G-Crosshaul simplifies and integrates the management and control processes across the whole 5G-Crosshaul infrastructure by the definition of mechanisms for an efficient use of network resources, infrastructure sharing and differentiated services within the 5G-Crosshaul network. We thus foresee the enablement of new possibilities as far as services are concerned:

1) Applications that run in a network-aware fashion. Examples of these are the CDN and TV broadcasting applications that 5G-Crosshaul is putting in place. Unlike traditional media distribution services, the CDN and TV broadcast services in 5G-Crosshaul are listening to the network and adapt their deployments according to the network context. Another example of applications that benefit from 5G-Crosshaul are the ones that run on the mobile edge using a cloud model. Mobile Edge Computing (MEC) opens up new possibilities not only related to network

functions (virtualized functions that run at the edge) but also for end user applications which can be downloaded and executed in-network. This is particularly interesting when processing involves more than one device, and converging sources on the network, such as an image processing application using multiple locations and feeds such as those existing in M2M or IoT scenarios.

2) Multi-tenancy scenarios, in which operations are carried out in a shared environment. The same physical infrastructure is used by several tenants or service providers. This fosters innovation by avoiding costly infrastructure investments and creates new commercial partnerships among all the actors within the value chain. Of course, this requires a trust framework to boost cooperation and also to control self-performance.

ATOS partner in particular anticipates potential exploitation of the two above aspects in new services and new business relationships as follows:

- For new services:
    - Evolving its Telco Network Portfolio (based on a Next Generation Intelligent Network Platform) to adopt 5G oriented solutions in order to position this product set in the market.
    - Getting CDN solutions ready for 5G.
- For new business relationships:
    - BSS consolidation and harmonization: ATOS harmonizes telecom processes, helping our customers streamline their vendor landscape and consolidating their technology using a systematic methodology which removes cost, cuts time and limits project risk. This allows operators to drive new kinds of customer relationships based on service speed, flexible pricing and unique brand reach. ATOS combines business process expertise with global integration skills, driving fresh value as the CRM, billing and other functionalities within BSS are transformed. With the adoption of NFV and 5G-Crosshaul solutions, this ATOS' offering will be boosted since vendor lock-in will be eliminated and greater flexibility will be achieved. ATOS will contemplate that some of the network functions will be virtualized and, at the same time, legacy solutions might remain, either temporarily as NFV advances, or in the long run (critical functions might not be virtualized). All these aspects have to be taken into account in order to drive these changes along with our telco customers. ATOS can help operators rationalize their systems before adopting NFV, which is essential for a successful uptake.
    - As far as cloud and virtualisation are concerned, of course, ATOS expects to play an important role in the telecom arena as a Cloud Infrastructure Provider, hosting virtualized network functions. At the moment, there are cloud services for IT but it is expected that telecom services will be delivered in a cloud fashion as well.

5.3 Key Innovations Identified in Year 1

The 5G-Crosshaul project targets innovations around three pillars of the future 5G transport network. These include: (1) Innovations for data-plane integration across the heterogeneous transmission technologies; (2) Innovations for a unified programmable control; and (3) Novel network applications running on top for optimizing the overall system performance. All these innovations are glued together into an innovative architecture framework that takes into account both technical and techno-economical requirements from the stakeholders of the value chain, namely operators, vendors and service operators.

In the first year, significant progress has been made to bring in early innovations that the project can build on and nurture further in the following years. These are presented briefly below.

1) An innovative design for the data plane that allows for the multiplexing of various 5G backhaul and fronthaul data across heterogeneous transmission and switching technologies. The innovative design featured novel framing procedures, under the umbrella of so-called XCF – Crosshaul Common Frame, both for packet-switching and circuit-switching, raising the potential for exploitation in two new products, namely XPFE – Crosshaul Packet Forwarding Element, and XCSE – Crosshaul Circuit Switching Element. The concept of an adaptation unit (XAU – Crosshaul Adaptation Unit) has also been proposed, to allow for integration between XCSE and XPFE as well as interoperation with other non-XCF technology domains. This might lead to new features that can be exploited in new products. Alongside these innovations, the project has also researched and developed new transmission technologies for high capacity both optical and wireless, and analysed their respective domain of suitability for a cost-efficient deployment in the service coverage-area.
2) A novel method for common abstraction of the data-plane technologies towards the control infrastructure (so-called XCI), which will help in the design of the south-bound interface of the controller, and in providing a common forwarding model to build upon in the design of the controller. This method aims at exposing in the most common way possible parameters and resources of the underlying data-plane technologies, so that one can facilitate the integration of all these technologies under common control and orchestration. In order to assess the proposed method, a design based on OpenFlow has been provided. This design results in novel extensions proposed to current implementation of OpenFlow Standard, and would hence lead to adoption in future releases of the OpenFlow standard.
3) First novel network applications that can optimize the overall system performance. As an example, the EMMA - Energy Management and Monitoring Application has been designed to consistently optimize the use of the energy consumption of the network infrastructure. This enables a sustainable approach to dynamically activate/deactivate networking resources to reduce energy and hence save costs. Importantly, the framework for the development of novel network applications has been laid down and more applications are under development and

hence expected to yield future innovations that can be packaged into new product or service offering.

All the above innovations are driven primarily by the need to make the future 5G transport network more flexible in order to ease and hence accelerate the deployment of new services, whilst guaranteeing cost-efficient use of all the resources in play. They have therefore a good potential for exploitation in new standards and products by the industrial stakeholders, notably network vendors, telecom operators and IT service providers.

Based on above innovations, we have drawn a first mapping onto PoCs, products, services and applications, under development by the project partners. This is depicted in Table 14 below.

Table 14: Mapping between project innovations and relevant partners' PoCs, Products, Services and Applications.

Innovation	PoC / Product / Service	Partner
XPFE	eNB with flexible functional split PoC	CND
	Radio Dot System	Ericsson
	Router 6000 family	
	EdgeLink mmWave nodes	InterDigital
	iPASOLINK converged packet radio	NEC
	Flexi Multiradio 10 Base Station	Nokia
	Ethernet VLAN switch	
XCSE	Fronthaul 6000	Ericsson
	Optical forwarding elements	
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
Network Apps	CDN	ATOS
	TV broadcasting	Visiona
	Energy efficiency management and monitoring	Nextworks / Polito
	Mobility management	UC3M / ITRI

5.4 Work Plan for Year 2

The exploitation strategy developed and executed upon in Year 1 remains valid for Year 2, with potential refinement as new innovations, PoCs, products, services, and applications emerge. In particular in Year 2, it is anticipated that more innovations will come out of the project and get validated through a number of test beds and trials planned in WP5. This will help to better address and motivate the uptake of these innovations into products and services by not only the project partners but also industrial stakeholders outside the project. We therefore intend to devote our efforts in Year 2 to:

- Identify further innovations from the project as they emerge and get validated through test beds and trials.
- Leverage on the test beds and trials to build a compelling story to promote these innovations to industrial stakeholders inside and outside the project consortium.

6 Conclusions

This document reported the progress on communication, dissemination, collaboration, standardization and exploitation activities, for the first year of 5G-Crosshaul project, i.e. July 2015 to June 2016. According to the reported progress for dissemination activities, it is clear that the consortium has achieved significantly more than the targets set in Work Plan of Year 1. Specially, 33 scientific journal or conference papers have been published (compared to 15 scientific publications as planned), while 37 talks have been delivered by the consortium partners (compared to the planned target of 10 talks). On the other hand, the partners have managed to hold 7 workshops and conducted 12 demonstrations throughout Year 1. Moreover, the dissemination plans for Year 2 are presented, which puts emphasis on proof-of-concept demonstrations and trials.

In order to bring impacts of this project to the specifications of new standards, various standard activities have been carried out to serve such purposes. The report has updated the status of several standardization bodies relating to 5G-Crosshaul project, as well as the standardization dissemination and contribution activities that have been undertaken by the consortium partners during Year 1. Examples of these latest updates include 3GPP's plan to specify the new fronthaul interface, IEEE 802.1CM, IEEE 1914 PAR, ITU-T, IETF IMT2020 Focus Group, ONF, and BBF. In addition, a roadmap for standardization work ahead (from now till 2020) is given in this report to illustrate the potential impacts of this project to different standards.

Exploitation of the innovations is also a key pillar to the activities. This report highlights the pre-commercial proof-of-concepts, commercial products and services from the project partners that might have an impact from/to the project. It also summarizes the key innovations identified from the project in year 1 and attempts a mapping of these innovations on relevant PoCs, products, services and applications from the project partners. Insights into the exploitation for Year 2 have also been provided.

In general, this report summarises the achievements of WP6 in Year 1, and showcases a remarkable milestone for dissemination activities of this project. Meanwhile, the vision of standard activities and exploitation plans are also elaborated, which offers a guideline for WP6 work of 5G-Crosshaul project in the following year.

Appendix A. Project kick-off press releases

The project issued a press release on 1st of July 2015 at the event of its kick off. The press release can be found under: http://5g-crosshaul.eu/xhaul-kick-off/

A number of communications by the partners has followed on to ensure wide reach of the press release. Samples of these communications are provided below for references:

- http://www.networks.imdea.org/whats-new/news/2015/european-industrial-academic-partners-join-develop-integrated-fronthaul-backhaul-solution-5g-networks
- http://netcom.it.uc3m.es/news/2015/european-industrial-and-academic-partners-join-develop-integrated-fronthaul-and-backhaul
- http://www.alphagalileo.org/ViewItem.aspx?ItemId=154810&CultureCode=en
- http://www.madrimasd.org/blogs/sociedadinformacion/2015/07/20/132730
- http://www.cttc.es/european-industrial-and-academic-partners-join-to-develop-the-integrated-fronthaul-and-backhaul-solution-for-5g-networks/
- http://ir.interdigital.com/releasedetail.cfm?releaseid=921645
- http://www.telematica.polito.it/public/project/xhaul-5g-integrated-fronthaulbackhaul
- http://www.corenetdynamics.com/2015/07/23/cnd-participating-on-xhaul-a-5g-ppp-project/
- https://blog.networks.nokia.com/mobile-networks/2015/07/21/11913/
- http://www.ericsson.com/research-blog/5g/x-haul-fronthaul-and-backhaul-network-research/
- http://www.communications.org.tw/en/events/item/8713-xhaul.html
- https://www.facebook.com/ITRI.ICL/posts/465312933642061
- Telefónica internal press release “forms part of Xhaul, an initiative to develop integrated transport solutions for the future 5G networks
- http://www.telecomkh.com/es/telefonia-movil/productos-y-servicios/8322
- http://gpsnews.es/not/6555/atos-impulsa-el-5g/
- http://es.atos.net/es-es/home/quienes-somos/noticias-y-eventos/noticias.html
- http://www.economiadehoy.es/noticia/4195/tecnologia/atos-impulsa-el-5g.html
- http://www.eleconomista.es/CanalPDA/2016/64688/atos-impulsa-el-5g/
- https://elcandelerotecnologico.com/2016/04/18/atos-impulsa-el-5g/
- http://www.silicon.es/atos-ayuda-a-definir-la-futura-red-5g-2306402
- http://digitalaffaires.es/not/2793/atos-impulsa-el-5g/
- http://www.infoperiodistas.info/notadeprensa/20450/Atos-impulsa-el-5G
- http://www.noticias2d.com/2016/04/18/atos-impulsa-el-5g/
- http://www.computing.es/internet/noticias/1088614001901/atos-participa-forma-activa-cinco.1.html

Appendix B. Activities prior to the project kick-off

Some additional dissemination activities were undertaken prior to the project kick-off in July, 2015. These activities are listed in Table 15 below. In total, the partners reported 11 talks and presentations, 2 panels, and 1 workshop organized.

Table 15 List of activities undertaken prior to project kick-off.

#	Month	Description	Partner
Talks and Presentations			
1	Oct'14	"Redes 5G: La revolucion de las comunicaciones" by A. Azcorra, Real Academia de Ingenieria, Madrid, Spain	UC3M
2	Nov'14	"5G Communications: A Thousand Times More Network Capacity" by A. Azcorra, Science Week, Madrid, Spain	UC3M
3	Jan'15	"Trends in EU research for 5G Networks" by A. Azcorra, 12th Italian Networking Workshop, Cavalese, Italy	UC3M
4	Apr'15	"5G Infrastructure PPP Overview", by A. De la Oliva, 5G IEEE ComSoC Pre-standardisation meeting, Piscataway, NJ, USA	UC3M
5	Apr'15	"Integrating Fronthaul and Backhaul" by A. De la Oliva, 5G IEEE ComSoC Pre-standardisation meeting, Piscataway, NJ, USA	UC3M
6	May'15	"Evaluating the different fronthaul options and the technical requirements for the different scenarios" by P. Chanclou, RAN&Backhaul, Berlin, Germany	ORANGE
7	Jun'15	"Mobile edge computing and network resource management" by J. Mangues, Small Cell World Summit, London, UK	CTTC
8	Jun'15	"Moving 5G Forward From Vision to Reality" by A. Carlton, IWPC, Bonn, Germany	IDCC
9	Jun'15	"Mapping the paths to 5G: A cellular perspective" by A. Mourad, LTE World Summit, Amsterdam, Netherlands	IDCC
10	Jun'15	"Elastic Optical Networks in a Converged Backhaul-metro beyond-5G Scenario" by A. De La Oliva, Joint Expert Group and Vision Group Workshop co-located with EuCNC2015, Paris, France	UC3M
11	Jun'15	"Access Network for 5G xHaul - Architectures and Optical Technology Requirements" by F. Cavaliere, Workshop "Short Reach Optical Networks Highly Synergistic or Different Worlds?" at OFC, California, USA	TEI
Panels			
1	Mar'15	"Getting standards ready for Fiber to the Antenna", by P. Chanclou, Panel about Optics in Access: Technology and Standards at OFC, California, USA	ORANGE
2	Jun'15	"Next Generation Backhaul/Fronthaul Networking and Communications: Challenges and Open Issues," within the IEEE Workshop on Next Generation Backhaul/Fronthaul Networks (BackNets 2015), in conjunction with IEEE ICC 2015, London, UK	NEC

Workshops			
1	Jun'15	Workshop "Mobile Edge Computing (MEC) with Small Cells" within the Small Cell World Summit. London, UK	ATOS

References

[1] http://5g-crosshaul.eu/wp-content/uploads/2015/11/5G-Crosshaul-vs-5G-Xhaul.pdf
[2] http://www.3gpp.org
[3] www.broadband-forum.org
[4] www.cpri.info
[5] www.etsi.org
[6] www.fsan.org
[7] www.ieee.org
[8] www.ietf.org
[9] http://www.itu.int/en/ITU-T/Pages/default.aspx
[10] www.ngmn.org
[11] www.opennetworking.org
[12] www.photonics21.org
[13] www.smallcellforum.org
[14] https://www.opennetworking.org/sdn-resources/openflow
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[17] https://www.ericsson.com/ourportfolio/products/radio-dot-system?nav=productcatagory006%7Cfgb_101_0516%7Cfgb_101_0526
[18] https://www.ericsson.com/ourportfolio/products/network-manager?nav=productcategory005%7Cfgb_101_0382
[19] http://www.nec.com/en/global/prod/nw/pasolink/
[20] http://www.nec.com/en/global/solutions/tcs/vepc/
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[22] http://networks.nokia.com/portfolio/products/mobile-broadband/single-ran-advanced/flexi-multiradio-10-base-station
[23] http://networks.nokia.com/portfolio/solutions/heterogeneous-networks