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Abstract:

This deliverable presents the CROWD project's overall achievements in terms of all dissemination and sustainability activities and plans. The list of achievements clearly demonstrates the productivity and sustainability of the collaboration between project partners.

Keywords:

energy efficiency, Long Term Evolution, WiFi, small cells, HetNets, DenseNets

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List of Project Partners

Name	Acronym	Country
Intecs S.p.A. (<i>coordinator</i>)	INCS	Italy
Alcatel-Lucent Bell Labs France	ALBLF	France
Fundacion IMDEA Networks	IMDEA	Spain
National Instruments	SIG	Germany
Universidad Carlos III de Madrid	UC3M	Spain
Universitaet Paderborn	UPB	Germany
Avea Iletisim Hizmetleri A.S.	AVEA	Turkey

List of Acronyms

CROWD Connectivity management for eneRgy Optimised Wireless Dense networks

EC European Commission

ECSG Executive Committee Privacy Recommendation Study Group

H2020 Horizon 2020

IEEE Institute of Electrical and Electronics Engineers

IETF Internet Engineering Task Force

IT Information Technology

MAC Medium Access Control

NFV Network Functions Virtualization

SDN Software Defined Network

Executive summary

The CROWD project proposed several solutions for very dense heterogeneous wireless access networks and integrated wireless-wired backhaul networks, in order to promote a paradigm shift in the future internet architecture towards global network cooperation, dynamic network functionality configuration and fine, on demand, capacity tuning. The details and performance results of these innovative solutions are disseminated through several channels. Moreover, future plans are constructed and various activities are implemented to support the sustainability of the CROWD project's solutions and outcomes. The purpose of this deliverable is to present the dissemination and sustainability activities and plans of the CROWD project that are developed during the project's lifespan.

Dissemination activities of the CROWD project are mainly presented under 15 categories. Throughout the lifespan of the project 15 journals and 2 white papers were published/accepted, 2 journals are currently under review, 39 conference papers and 9 posters were accepted, 6 demonstrations were presented, 11 invited talks and 1 tutorial sessions were held, 16 public deliverables were prepared, 1 workshop and 4 journal special sessions were organized, 33 students were trained resulting in 17 theses, 6 press releases were published, the CROWD project web site and social media platform were actively used and project partners' channels were utilized to disseminate the project's achievements.

The CROWD project's activities for sustainability are presented under 4 topics covering 32 standardization contributions, 1 technology transfer action and 5 new Horizon 2020 (H2020) projects.

The overall achievements of the CROWD project presented in this deliverable clearly demonstrates that the project has achieved its goals regarding dissemination and exploitation activities. The efficient and productive collaboration of the project partners has already shown its impact by proliferating new targets and partnerships.

1 Introduction

The CROWD project targets very dense heterogeneous wireless access networks and integrated wireless-wired backhaul networks and pursues four key goals to *i)* bring density-proportional capacity, *ii)* optimize Medium Access Control (MAC) mechanisms, *iii)* enable traffic-proportional energy consumption, and *iv)* guarantee mobile users quality of experience, by designing smarter connectivity management solutions. The consortium combines the integrated perspectives of a major mobile operator, a top leader manufacturer, a provider of test equipment, an innovative company engaged to develop new technologies, two leading academic partners and a world-renowned research institute.

The technology developed by the CROWD project for very dense heterogeneous wireless access networks and integrated wireless-wired backhaul networks takes into account the requirements for commercial deployment based on strategic areas. The project's exploitation activities comprise a thorough contributions to standardization activities through relevant groups at Internet Engineering Task Force (IETF), Institute of Electrical and Electronics Engineers (IEEE) and Executive Committee Privacy Recommendation Study Group (ECSG).

This document covers the activities concerning the contributions of the project, including the dissemination as well as sustainable activities such as standardization and plans with a specific focus on technology transfer to the industry. A major success of the project has been to introduce the project's results into standardization path and into exploitation plans of the different consortium partners. In fact, the CROWD project results are properly advertised and disseminated, and the dissemination of the results and scientific knowledge generated within the project have also been brought into the relevant standardization bodies. The CROWD project has also ensured high-level publications in the research community as well as presence in other kind of dissemination activities (such as demonstration events and organization of workshops). Tools such as CiteUlike, Arxiv and social networks are also used to advertise and maximize the dissemination of its scientific work. Moreover, 5 new H2020 projects have emerged thanks to the sustainable collaboration among the CROWD project partners.

The project's output has contributed to appropriate top-level scientific journals and conferences as well as the website has gathered all the public information of the project. A summary of all the dissemination activities are summarized in Table 1.1.

Activity Name	Number	Activity Name	Number
Journal papers	17	Patents filed	2
Conference papers	39	Special Issues Organized	4
Posters	9	Students trained	33
Demonstrations	6	Thesis	17
White papers	2	Press Releases	6
Invited talks	11	Standardization	32
Tutorials	2	New Projects	5

Table 1.1: A summary of dissemination activities

The rest of the document is organized as follows: Chapter 2 presents the dissemination activities carried out in the CROWD project. Chapter 3 highlights the sustainable activities and plans of the CROWD project where standardization, technology transfer and new projects are introduced. Finally, Chapter 4 summarizes and concludes the document.

2 Dissemination activities

In this chapter dissemination activities of the CROWD project are listed.

2.1 Journals

2.1.1 Submitted

1. M. Isabel Sanchez, A. de la Oliva, C.J. Bernardos ,“How does my smartphone manage network connections?”. submitted to Elsevier Computer Networks.
2. M. Isabel Sanchez, E. Zeydan, A. De la Oliva, A. Serdar Tan, U. Yabas and C.J. Bernardos,“Mobility Management: Deployment and Adaptability Aspects Thorough Mobile Data Traffic Analysis”, submitted to IEEE Network Magazine, Special Issue on Big Data for Networking.

2.1.2 Publication Pending

1. Carlos Donato, Pablo Serrano, Antonio de la Oliva, Albert Banchs, Carlos J. Bernardos, “An OpenFlow Architecture for Energy Aware Traffic Engineering in Mobile Networks”, accepted for publication in IEEE Network Magazine: Special Issue-Software Defined Wireless Networks, 2015.

2.1.3 2015

1. Pablo Serrano, Pablo Salvador, Vincenzo Mancuso, Yan Grunenberger, “Experimenting with Commodity 802.11 Hardware: Overview and Future Directions”, IEEE Communications Surveys and Tutorials, vol.17, no.2, Secondquarter 2015.
2. A. Asadi, V. Sciancalepore, and V. Mancuso, “On the efficient utilization of radio resources in extremely dense wireless networks” IEEE Communications Magazine, vol.53, no.1, pp.126-132, January 2015.

2.1.4 2014

1. A. Arash, Q. Wang, and V. Mancuso, “A Survey on Device-to-Device Communication in Cellular Network”, IEEE Communications Surveys and Tutorials, Vol.16, no.4, pp.1801-1819, Fourthquarter 2014.
2. A. Banchs, A. de la Oliva, L. Eznarriaga, D. R. Kowalski, P. Serrano, “Performance Analysis and Algorithm Selection for Reliable Multicast in IEEE 802.11aa Wireless LAN”, IEEE Transactions on Vehicular Technology, vol.63, no.8, pp.3875-3891, October 2014.
3. A. Asadi, P. Jacko, and V. Mancuso, “Modeling D2D Communications with LTE and WiFi”, ACM SIGMETRICS Performance Evaluation Review, vol.42, no.2, pp.55-57, September 2014.

4. A. Asadi and V. Mancuso, "DRONEE: Dual-Radio Opportunistic Networking for Energy Efficiency", Elsevier Computer Communications Journal, Green-Net Special Issue, Vol.50, pp.41-52, September 2014.
5. M. Isabel Sanchez, Marco Gramaglia, Carlos J. Bernardos, Antonio de la Oliva, Maria Calderon. "On the implementation, deployment and evaluation of a networking protocol for VANETs: the VARON case", Elsevier Ad Hoc Networks, Vol.19, pp.9-27, August 2014.
6. Pablo Serrano, Andres Garcia-Saavedra, Giuseppe Bianchi, Albert Banchs, Arturo Azcorra, "Per-frame Energy Consumption in 802.11 Devices and its Implication on Modeling and Design", IEEE/ACM Transactions on Networking, May 2014.
7. Carlos Guimaraes, Daniel Corujo, Antonio de la Oliva, Yoshihiro Ohba, Rui L. Aguiar, "Multicast group membership management in media independent handover services", in Elsevier Computer Networks, vol. 62, pp.55-68, January 2014.
8. Pablo Salvador, Luca Cominardi, Francesco Gringoli, Pablo Serrano, "A First Implementation and Evaluation of the IEEE 802.11aa Group Addressed Transmission Service", ACM Computer Communication Review, vol.44, no.1, pp.35-41, January 2014.

2.1.5 2013

1. Ivan Vidal, Jaime Garcia-Reinoso, Ignacio Soto, Antonio de la Oliva, "A solution for transparent mobility with route optimization in the IP multimedia subsystem", in Elsevier Computer Communications, vol.36, no.17, pp.1726-1744, November 2013.
2. M.Isabel Sanchez, A. Boukerche, "On the IEEE 802.11k/r/v amendments: do they have a real impact?", IEEE Wireless Communication Magazine, 2013.

2.2 Conference papers

2.2.1 2015

1. S. Auroux, H. Karl, "Flexible Reassignment of Flow Processing-aware Controllers in Future Wireless Network", in Proceedings of the 26th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), September, 2015.
2. C. Vitale, G. Rizzo, B. Rengarajan, V. Mancuso, "An Analytical Approach to Performance Analysis of Coupled Processor System", in proceedings of ITC27, Ghent, Belgium, September 2015.
3. A. Asadi, V. Mancuso, and P. Jacko, "Floating Band D2D: Exploring and Exploiting the Potentials of Adaptive D2D-enabled Network", in Proceedings of IEEE WoWMoM 2015, Boston, MA, USA, June 2015.
4. Pablo Salvador, Francesco Gringoli, Pablo Serrano, Nicol Facchi, Stefano Paris, "Making a Case for Flexible 802.11 Architectures", IEEE International Conference on Communications (ICC) - Mobile and Wireless Networking Symposium, London, UK, June 2015.
5. V. Sciancalepore, I. Filippini, V. Mancuso, A. Capone, and A. Banchs, "A semi-distributed mechanism for Inter-cell Interference Coordination exploiting the ABSF paradigm", in Proceedings of IEEE SECON 2015, Seattle, WA, USA, June 2015.

6. C. Vitale, G. Rizzo, V. Mancuso, "A Coupled Processors Model for 802.11 Ad Hoc Networks Under Non Saturation", in Proceedings of IEEE ICC 2015, London, UK, June 2015.
7. S. Auroux, M. Dräxler, A. Morelli, and V. Mancuso, "Dynamic Network Reconfiguration in Wireless DenseNets with the CROWD SDN Architecture", in Proceedings of EuCNC 2015, Paris, France, June 2015.
8. R. Gupta, B. Bachmann, R. Ford, S. Rangan, N. Kundargi, K. Rathi, M. I. Sanchez, A. de la Oliva, A. Morelli, "NS-3-based Real-time emulation of LTE Testbed using LabVIEW platform for Software Defined Networking (SDN) in CROWD Project", in Proceedings of Workshop on NS-3 (WNS3), Barcelona, Spain, May 2015.
9. M. Isabel Sanchez, Arash Asadi, Martin Drxler, Rohit Gupta, Vincenzo Mancuso, Arianna Morelli, Antonio de la Oliva and Vincenzo Sciancalepore, "Tackling the increased density of 5G networks; the CROWD approach", 5GARCH VTC Spring, Glasgow (United Kingdom), May 2015.
10. M. I. Sanchez, A. Asadi, M. Draexler, R. Gupta, V. Mancuso, A. Morelli, A. de la Oliva and V. Sciancalepore, "Tackling the increased density of 5G networks; the CROWD approach", in Proceedings of VTC2015-Spring (5GArch 2015 Workshop), Glasgow, Scotland, UK, May 2015.
11. Jorge Ortn, Pablo Serrano, Carlos Donato, "Modeling the Impact of Start-Up Times on the Performance of Resource-on-Demand Schemes in 802.11 WLANs", Sustain IT - The 4th IFIP Conference on Sustainable Internet and ICT for Sustainability, Madrid, Spain, April, 2015.
12. R. Gupta, R. Ford, B. Bachmann, N. Kundargi, A. Ekbal, K. Rathi, V. Mancuso, A. Morelli, S. Rangan, A. Kruppe, A. Asadi, "LabVIEW based Software-Defined Physical/MAC layer architecture for prototyping dense LTE Networks", in Proceedings of WinnComm 2015, March 2015.
13. S. Auroux, H. Karl, "Efficient Flow Processing-aware Controller Placement in Future Wireless Networks", in Proceedings of IEEE Wireless Communications and Networking Conference (WCNC), March, 2015.
14. M. Dräxler, J. Blobel, P. Dreimann, S. Valentin, H. Karl, "SmarterPhones: Anticipatory Download Scheduling for Wireless Video Streaming", in International Conference on Networked Systems (NetSys), March, 2015.

2.2.2 2014

1. R. Gupta, A. Ekbal, A. Nahler, V. Mancuso, A. De La Oliva, A. Morelli, R. Ford, and S. Rangan, "LabVIEW based Platform for prototyping dense LTE Networks", in proceedings of GLOBECOM 2014, December 2014.
2. E. Christoforou, A. Fernández Anta, A. Santos, "A Mechanism for Fair Distribution of Resources with Application to Sponsored Search", in proceedings of Web and Internet Economics (WINE) 2014, Beijing, China, December 14-17, 2014.
3. M. Dräxler, P. Dreimann, H. Karl, "Anticipatory Power Cycling of Mobile Network Equipment for High Demand Multimedia Traffic", in IEEE Online Conference on Green Communications, November, 2014.

4. R. Gupta, B. Bachman, R. Ford, S. Rangan, A. Morelli, V. Mancuso, N. Kundargi, and A. Ekbal, "DEMO: LabVIEW based framework for prototyping dense LTE networks", in proceedings of WiNTECH 2014, September 2014.
5. N. Trabelsi, L. Roullet, A. Feki, "A Generic Framework for Dynamic eICIC Optimization in LTE heterogeneous Networks", in IEEE Vehicular Technology Conference 2014, September 2014.
6. S. Auroux, H. Karl, "Flow processing-aware Controller Placement in Wireless DenseNet", in Proceedings of the 25th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), September, 2014.
7. Amir Darehshoorzadeh , M. Isabel Sanchez and Azzedine Boukerche, "Modeling and Analysis of Opportunistic Routing in Multi-hop Wireless Networks", in MASCOTS 2014, Paris, September 2014.
8. M. Dräxler, H. Karl, "SmarterPhones: Anticipatory Download Scheduling for Segmented Wireless Video Streaming", in 1st KuVS Workshop on Anticipatory Networks, September, 2014.
9. C. Bottai, C. Cicconetti, A. Morelli, M. Rosellini, C. Vitale, "Energy-Efficient User Association In Extremely Dense Small Cell Networks", in proceedings of EuCNC 2014, Bologna, Italy, June 2014.
10. R. Gupta, T. Vogel, N. Kundargi, A. Ekbal, A. Morelli, V. Mancuso, V. Sciancalepore, R. Ford, and S. Rangan, "LabVIEW based Platform for prototyping dense LTE Networks in CROWD Project, in proceedings of EuCNC 2014, Bologna, Italy, June 2014.
11. A. Asadi, P. Jacko, and V. Mancuso, "Modeling Multi-Mode D2D Communications in LTE", in proceedings of ACM SIGMETRICS MAMA 2014, Austin, TX, USA, June 2014.
12. P. Wette, M. Dräxler, A. Schwabe, F. Wallaschek, M. Hassan Zahraee, H. Karl, "MaxiNet: Distributed Emulation of Software-Defined Networks", in Proceedings of the 2014 IFIP Networking Conference, June 2014.
13. V. Sciancalepore, V. Mancuso, A. Banchs, S. Zaks, A. Capone, "Interference Coordination Strategies for Content Update Dissemination in LTE-A", in proceedings of INFOCOM 2014, Toronto, Canada, May 2014.
14. M. Dräxler, H. Karl, "Feasibility of Base Station Coordination and Dynamic Backhaul Network Configuration in Backhaul Networks with Limited Capacity", in European Wireless 2014 (EW2014), May, 2014.

2.2.3 2013

1. H. Ali-Ahmad, C. Cicconetti, A. de la Oliva, V. Mancuso, M. R. Sama, P. Seite, and S. Shanmugalingam, "An SDN-based Network Architecture for Extremely Dense Wireless Networks", in proceedings of 2013 Software Defined Networks for Future Networks and Services (SDN4FNS'13), Trento, Italy, November 2013.
2. H. Ali-Ahmad, C. Cicconetti, A. de la Oliva, M. Draexler, R. Gupta, V. Mancuso, L. Roullet, and V. Sciancalepore, "CROWD: An SDN Approach for DenseNet", in proceedings of EWSDN13, Berlin, Germany, October 10, 2013.

3. A. Asadi and V. Mancuso, "WiFi Direct and LTE D2D in Action", in proceedings of Wireless Days13, Valencia, Spain, 1315 November 2013 (Best paper award runner-up).
4. H. Ali-Ahmad, C. Cicconetti, A. de la Oliva, V. Mancuso, M. R. Sama, P. Seite, and S. Shanmugalingam, "An SDN-based Network Architecture for Extremely Dense Wireless Networks", at SDN4FNS13, November 2013.
5. A. Asadi, and V. Mancuso, "On the Compound Impact of Opportunistic Scheduling and D2D Communications in Cellular Networks", in proceedings of ACM/IEEE MSWiM'13, Barcelona, Spain, November 38, 2013.
6. H. Ali-Ahmad, C. Cicconetti, A. de la Oliva, M. Dräxler, R. Gupta, V. Mancuso, L. Roullet, V. Sciancalepore: CROWD, "An SDN Approach for DenseNets", in Second European Workshop on Software Defined Networks, October 2013.
7. M. Isabel Sanchez, Carlos J. Bernardos, Antonio de la Oliva and Pablo Serrano, "Energy consumption savings with 3G offload", CLEEN Workshop, collocated with VTC2013-Fall, Las Vegas, USA, September 2013.
8. H. Ali-Ahmad, C. Cicconetti, A. de la Oliva, M. Draexler, R. Gupta, V. Mancuso, L. Roullet, and V. Sciancalepore, "CROWD: An SDN Approach for DenseNets", at EWSDN13, September 2013.
9. C. Cicconetti, A. Morelli, M. Draxler, H. Karl, V. Mancuso, V. Sciancalepore, R. Gupta, A. de la Oliva, I. Sánchez, P. Serrano, L. Roullet, "The Playground of Wireless Dense Networks of the Future", in Future Network and Mobile Summit 2013, July 2013.

2.2.4 2012, work related to CROWD

1. A. de la Oliva, A. Morelli, V. Mancuso, M. Draexler, T. Hentschel, T. Melia, P. Seite and C. CicconettiDenser, "Networks for the Future Internet, the CROWD approach", to be presented at the MONAMI OConS Workshop: Workshop on Open Connectivity Services for the Future Internet, Hamburg, Germany, September 24-26, 2012.

2.3 Posters

2.3.1 2015

1. A. Asadi, V. Mancuso, R. Gupta, "An SDR-based Experimental Study of Outband D2D Communications", 7th IMDEA networks annual workshop, Madrid, June, 2015.
2. C. Vitale, V. Mancuso, and G. Rizzo, "Optimizing in-band underlay D2D transmissions", 7th IMDEA networks annual workshop, Madrid, June, 2015.
3. C. Vitale, V. Mancuso, and G. Rizzo, "Modelling D2D Communications in Cellular Access Networks via Coupled Processors", COMSNETS 2015, Bangalore, India (student poster associated to a full paper), January 2015.

2.3.2 2014

1. A. Morelli, R. Gupta, M. Draxler, H. Karl, V. Mancuso, A. de la Oliva, E. Bizouarn, E. Zeydan, "The CROWD framework for tackling challenges of dense small cell deployments using Software Defined Networking (SDN)", GLOBECOM 2014 Industry Program, December 2014.

2. C. Vitale, V. Mancuso, and G. Rizzo, "Modelling D2D Communications in Cellular Access Networks via Coupled Processors", 6th IMDEA networks annual workshop, Madrid, June, 2014.
3. A. Arash, P. Jacko, and V. Mancuso, "Mind the ties", 6th IMDEA networks annual workshop, Madrid, June 2014.

2.3.3 2013

1. C. Cicconetti, A. Morelli, A. de la Oliva, V. Mancuso, M. Draexler, "Connectivity management for eneRgy Optimised Wireless Dense networks", FUNEMS 2013, July 2013.
2. A. Asadi and V. Mancuso, "Energy Efficient Opportunistic Uplink Packet Forwarding in Hybrid Wireless Networks", 5th IMDEA networks annual workshop, Madrid, June, 2013.
3. H. Ali-Ahmad, C. Cicconetti, M. Draexler, R. Gupta, V. Mancuso, A. Morelli, L. Roullet, M. I. Sanchez, V. Sciancalepore, "The Playground of Wireless Dense Networks of the Futures", Future Network & Mobile Summit 2013, Lisbon, Portugal, July, 2013.

2.4 Patents filed/granted

1. Laurent Roullet, "Virtual scheduler: Method, equipment and computer readable medium for allocating resources", European Patent Office, 2015.
2. Laurent Roullet, "eICIC over X2 proxy", European Patent Office, 2014.

2.5 Demonstrations

2.5.1 2015

1. Arash Asadi, Vincenzo Mancuso, and Rohit Gupta, "A LabView-based platform for Outband D2D communications", EUCNC, 2015, June 2015.

2.5.2 2014

1. R. Gupta, A. Ekbal, A. Nahler, V. Mancuso, A. De La Oliva, A. Morelli, R. Ford, and S. Rangan, "LabVIEW based Platform for prototyping dense LTE Networks", in proceedings of GLOBECOM 2014 (with associated paper in the Industry Program), December 2014.
2. C. Vitale, R. Gupta, V. Mancuso, A. Morelli, "A prototyping methodology for SDN-controlled LTE using LabVIEW SDR and NS3", Demo at ETSI workshop on Reconfigurable Radio Systems, Sophia Antipolis, France, December, 2014.
3. R. Gupta, B. Bachman, R. Ford, S. Rangan, A. Morelli, V. Mancuso, N. Kundargi, and A. Ekbal, "DEMO: LabVIEW based framework for prototyping dense LTE networks", in proceedings of WiNTECH 2014 (with associated paper in the Demo/Poster Session), September 2014.
4. LabVIEW prototyping for dense LTE (FP7 CROWD), exhibitor at EuCNC 2014, June 2014.

2.5.3 2013

1. Fabio Giust, Antonio de la Oliva, Carlos J. Bernardos, “Mobility Management in Next Generation Mobile Networks - [Demo]”, IEEE WoWMoM 2013, Madrid, Spain, June, 2013.

2.6 White papers

1. “5G Radio Network Architecture”, edited by the Radio Access Spectrum, FP7 Future Networks Cluster. (contributed by Antonio de la Oliva)
2. “5G: Challenges, Research Priorities and Recommendations”, by the European Technology Platform for Communications Networks and Services, NetWorld2020 EP. (contributed by Antonio de la Oliva)

2.7 Invited talks

2.7.1 2015

1. V. Mancuso, “Energy efficiency in very dense wireless networks through opportunistic radio resource utilization”. Joint CLEEN and ACROSS Workshop on Cloud Technology and Energy Efficiency in Mobile Communications, EuCNC 2015, Paris, June 29th, 2015.
2. V. Mancuso, Panelist at the joint CLEEN and ACROSS Workshop on Cloud Technology and Energy Efficiency in Mobile Communications, EuCNC 2015, Paris, June 29th, 2015.
3. V. Mancuso, “Opportunistic resource allocation in dense cellular networks”. iJOIN winter School, Bremen, Germany, February, 23rd, 2015.
4. H. Karl, “Design Aspects of Network Function Virtualization”, Summer School for Master and PhD Students on NFV meets Big Data, Wrzburg, Germany, April, 2015
5. Pablo Serrano, “Control theoretic optimization of 802.11 WLANs: Design, implementation and experimental evaluation of two schemes”, Trinity College Dublin, June 10th, 2015.

2.7.2 2014

1. H. Karl, “SDN & NFV - Hoffnung oder Hype?”, ZKI Herbsttagung, Kaiserslautern, Germany, September 22-24, 2014
2. Pablo Serrano, “Greening Wireless Communications: A Top-Down Overview”, University of Edinburgh, March 7th, 2014.
3. Pablo Serrano, Greening (Heterogeneous) Wireless Networks: Overview and Future Directions, Universidad Pompeu Fabra, Barcelona, February 27th, 2014.

2.7.3 2013

1. V. Mancuso, “Advanced Technologies for Extremely Dense and Heterogeneous Wireless Networks”, Advanced Small Cell Deployments and Cloud Technologies (IPWC workshop), Turin, November 12-14, 2013.
2. V. Mancuso, Panelist at Advanced Small Cell Deployments and Cloud Technologies (IPWC workshop), Turin, November 12-14, 2013.

3. Antonio de la Oliva participated in the National Instruments round table. This event was useful to disseminate CROWD ideas and get to know what other researchers in the field are doing with NI hardware, Lyon, France, December 3rd, 2013.

2.8 Tutorials

1. P. Wette, M. Dräxler, “SDN Experimentation Tools for Large-Scale Experiments”, given at MONAMI 2014 in Würzburg, Germany, 2014.
2. Antonio de la Oliva, spoke at the Wireless SDN in Access and Backhaul tutorial to the IEEE 802 plenary, held in Dallas, November 2013. (<http://ieee802.org/Tutorials.shtml>)

2.9 Projects public deliverables

1. D1.1: Preliminary architecture design
2. D1.2: Business cases, economic and migration scenarios analysis
3. D1.3: Final architecture design
4. D1.4: Final plan for the use of dissemination of foreground
5. D2.1: Initial specification of wireless enhancements for very dense deployments
6. D2.2: Final specification for the wireless enhancements functions and interfaces
7. D2.3: Final assessment on MAC enhancements and cooperation techniques
8. D3.1: Initial specification of Dynamic Radio and Backhaul configuration mechanisms
9. D3.2.: Final specification of functions and interfaces of Dynamic Radio and Backhaul configuration mechanisms
10. D3.3: Final report on case studies and analysis for Dynamic Radio and Backhaul configuration mechanisms
11. D4.1: Initial specification of Connectivity Management concepts and architecture
12. D4.2: Consolidated specification for the Connectivity Management functions and interfaces
13. D4.3: Final assessment on Connectivity Management for very dense scenarios
14. D5.1: First integration report and intermediate software release
15. D5.2: Second integration report and performance evaluation results
16. D5.3: Report of demonstration and final software release

2.10 Workshops organized

1. “5G network revolution”, 6th IMDEA networks annual workshop, Madrid, June, 2014.

2.11 Special issues organized

1. Elsevier PHYCOM, Special issue on D2D-based Offloading Techniques (Ongoing as of July 2015)
2. IEEE Wireless Communication Magazine, Special issue on social aware D2D communications (Ongoing as of July 2015)
3. C. Cicconetti, A. de la Oliva, D. Chieng, J.C. Zuniga, “Guest Editorial, Extremely Dense , Wireless Networks”, IEEE Communications Magazine Special Issue on Extremely Dense Wireless Networks, January 2015.
4. Pablo Serrano, Xavier Costa-Prez, Jinsong Wu and Ken Christensen, “Special Issue: Green Communications”, Computer Networks Volume 78, Pages 1-202, February 2015.

2.12 Students trained

1. Andrés Garca Saavedra(PhD Student)
2. Angelos Chatzipapas (PhD Student)
3. Arash Asadi (PhD Student)
4. Aravinthan Gopalasingham (PhD student)
5. Carlos Donato Morales (PhD Student)
6. Carlota Villasante Marcos(Undergrad Student)
7. Christian Vitale (Master and PhD Student)
8. Dario Ceron (Undergrad Student)
9. David Galera (Internship)
10. Diego Grande Benito (Undergrad Student)
11. Dora Boviz (PhD student)
12. Enrique Herreros Jiménez (Undergrad Student)
13. Fernando Garca Garca (Undergrad Student)
14. Giulia Resmini (Internship)
15. Ioanna Dak (Master student)
16. Jason Moorcroft (Undergrad Student)
17. Javier de Benito Ruiz (Undergrad Student)
18. Johannes Blobel (Master student)
19. Jose Pablo Salvador(PhD Student)
20. Julian Merino (Undergrad Student)
21. Maria Isabel Snchez Bueno (PhD Student)

22. Mario Rodriguez Blanco (Undergrad Student)
23. Martin Dräxler (PhD student)
24. Nessrine Trabelsi (PhD student)
25. Omar Ahmad San Jos (Master student)
26. Pablo Castellanos (Undergrad Student)
27. Philipp Dreimann (Master student)
28. Sébastien Auroux (PhD student)
29. Simone Mattiacci (Master and PhD Student)
30. Stylianos Moschos (Internship)
31. Swante Scholz (Bachelor student)
32. Vasileios Papadopoulos (Undergrad Student)
33. Vincenzo Sciancalepore (PhD Student)

2.13 Theses

1. Giulia Resmini, BSc at Polytechnic of Milan, Italy, thesis to be defended.
2. Carlota Villasante Marcos, “Study of the randomizations of MAC addresses in WLAN”, Bachelor Thesis, Expected Nov 2015
3. Jason Moorcroft, “Integration of NI LTE module in CROWD DMM platform”, Bachelor Thesis, Expected Nov 2015
4. Swante Scholz, “A genetic algorithm for flow processing-aware controller placement”, B.Sc. at UPB, ongoing
5. Martin Dräxler, “Resource Allocation and Scheduling in Dense Mobile Access Networks”, PhD at UPB, 12.06.2015
6. Mario Rodriguez Blanco, “Surveillance tool for very-populated WiFi Networks”, Grado en Ingeniera Telemática, 09.03.2015
7. Ioanna Dak, “Deployment of an IEEE 802.11u information server with SDN control”, Master Thesis, Jan 2015
8. Johannes Blobel, “Anticipatory Video Buffering Under Uncertain Predictions”, M.Sc. at UPB, 15.12.2014
9. Philipp Dreimann, “Anticipatory Power Cycling of Mobile Network Equipment for High-Demand Multimedia Traffic”, M.Sc. at UPB, 18.04.2014
10. Christian Vitale, “Performance Bounds in Coupled Processor Systems”, MSc at University Carlos III or Madrid UC3M, Spain, 28.10.2013.

11. Stylianos Moschos, “A Novel Genetic Algorithmic Approach to Coordinate Base Station Transmissions in LTE Cellular Networks”, BSc at Alexander technological educational institute of Thessaloniki, Greece, July 2013.
12. Andrés Garca Saavedra, “Analysis and Optimal Configuration of Distributed Opportunistic Scheduling Techniques in Wireless Networks”, PhD Telematics Engineering, Director: Albert Banchs, Co-Director: Pablo serrano, 13.11.2013
13. Julian Merino, “Analysis of topology formation algorithms in SDN”, Bachelor Thesis, Nov 2014
14. Fernando Garca Garca, “IEEE 802.11aa OMNET++ model upgrading”, Bachelor Thesis, Nov 2014
15. Pablo Castellanos, “Optimisation of the CROWD DMM base code”, Bachelor Thesis, July 2014
16. Simone Mattiacci, “Interference mitigation and User Association algorithms for resource optimization in future DenseNets”, University of Pisa, 28.04.14.
17. Dario Ceron, “Development of the CROWD DMM base code”, Bachelor Thesis, March 2014

2.14 Press releases

1. CROWD selected “early 5G precursor project” (June 4, 2014, <http://www.networks.imdea.org/whats-new/news/2014/crowd-selected-early-5g-precursor-project>)
2. CROWD Kick-off meeting (January 8, 2013, <http://www.networks.imdea.org/whats-new/events/2013/crowd-kick-meeting>)
3. Vincenzo Mancuso presents CROWD project at Telecom Italia Workshop (November 25, 2013, <http://www.networks.imdea.org/whats-new/news/2013/vincenzo-mancuso-presents-crowd-project-telecom-italia-workshop>)
4. Exploiting network density in mobile communications (April 4, 2013, <http://www.networks.imdea.org/whats-new/news/2013/exploiting-network-density-mobile-communications>)
5. The 5G Network Revolution (May 30, 2014, <http://www.networks.imdea.org/whats-new/news/2014/5g-network-revolution>)
6. CROWD participated at the social media event in Turkey, during the 6th Plenary meeting, held by AVEA(26th Sept 2014) (<http://finans.mynet.com/haber/detay/ekonomi/avea-5g-projesi-crowda-dahil-oldu/96450>)

2.15 Web

1. CROWD web site, <http://www.ict-crowd.eu/>, has been used actively to disseminate the project results and news.
2. CROWD twitter account, @FP7CROWD, has been actively used to announce CROWD activities and achievements.

2.16 Partners channels

1. Project partner NI has used their partner channels to disseminate CROWD achievements and activities; <http://www.ni.com/white-paper/52339/en/>

3 Sustainability activities and plans

In this chapter sustainability activities and plans of the CROWD project are listed.

3.1 Standardization

3.1.1 IETF

1. T. Melia and S. Gundavelli (Author list in page 17), Logical Interface Support for multi-mode IP Hosts, (draft-ietf-netext-logical-interface-support-11), March 2015.
2. C.J. Bernardos, A. de la Oliva, F. Giust, A PMIPv6-based solution for Distributed Mobility Management, (draft-bernardos-dmm-pmip-04), March 2015.
3. C.J. Bernardos, A. de la Oliva, F. Giust, An IPv6 Distributed Client Mobility Management approach using existing mechanisms, (draft-bernardos-dmm-cmip-03), March 2015.
4. C.J. Bernardos, Proxy, Mobile IPv6 Extensions to Support Flow Mobility (draft-ietf-netext-pmipv6-flowmob-13), February 2015.
5. H. Chan, D. Liu (Author list on P.17), Requirements for Distributed Mobility Management (draft-ietf-dmm-requirements-09), December 2013.
6. D. Liu, JC. Zuniga, P. Seite, H. Chan, CJ. Bernardos, Distributed Mobility Management: Current practices and gap analysis, draft-ietf-dmm-best-practices-gap-analysis-05, IETF Internet draft, June 2013.
7. JC. Zuniga, LM. Contreras, CJ. Bernardos, S. Jeon, Y. Kim, Multicast Mobility Routing Optimizations for Proxy Mobile IPv6, draft-ietf-multimob-pmipv6-ropt-06, IETF Internet draft, June 2013.

3.1.2 IEEE 802 EC SG Omniran (IEEE 802.1cf)

1. Antonio de la Oliva (UC3M), Juan Carlos Zuniga (InterDigital), Luis Contreras (Telefonica), Roger Marks (EthAirNet Associates), Generic IEEE 802 Network Reference Model, Nov 2014.
2. Juan Carlos Zuniga (InterDigital), Antonio de la Oliva (UC3M), Paul Congdon (Tallac), SDN-based Use Cases for BoF, <https://mentor.ieee.org/omniran/dcn/14/omniran-14-0029-00-0000-sdn-based-use-cases-for-bof.pptx>, Mar-2014
3. Juan Carlos Zuniga (InterDigital), Antonio de la Oliva (UC3M), SDN Use Case ToC, <https://mentor.ieee.org/omniran/dcn/14/omniran-14-0007-01-0000-sdn-use-case-toc.pptx>, January 2014
4. Roger Marks, Antonio de la Oliva, Juan Carlos Zuniga, Proposed OMNIRAN SDN use case for external communication, <https://mentor.ieee.org/omniran/dcn/13/omniran-13-0059-00-0000-proposed-omniran-sdn-use-case-for-external-communication.pptx>, Sept 2013
5. Roger Marks, Antonio de la Oliva, Juan Carlos Zuniga, SDN Use case Summary, <https://mentor.ieee.org/omniran/dcn/13/omniran-13-0044-02-0000-sdn-use-cases-summary.pptx>, Sept 2013

6. A. de la Oliva, PAR and 5C Text comments, <https://mentor.ieee.org/omniran/dcn/13/omniran-13-0076-00-0000-par-and-5c-text-comments.docx>, Sept 2013
7. A. de la Oliva, J.C. Zuiga and C. Perkins, SDN-based approach for OmniRAN, March 2013. <https://mentor.ieee.org/omniran/dcn/13/omniran-13-0022-00-0000-sdn-based-approach-for-omniran.pptx>
8. Antonio de la Oliva, 3GPP SA2 SaMOG Status, Presented on February 2013 OMNIRAN AC, <https://mentor.ieee.org/omniran/dcn/13/omniran-13-0012-00-0000-samog-status.pptx>
9. Antonio de la Oliva Carlos, Carlos Jesus Bernardos; Ivano Guardini, Loris Marchetti, OmniRAN 3GPP SaMOG, Presentation to IEEE 802.16 HetNet SG (that become OMNIRAN in January 2013). <https://mentor.ieee.org/802.16/dcn/12/16-12-0660-00-Shet-omniran-3gpp-samog.pptx>.
10. A. de la Oliva, J. C. Zuniga, and Roger Marks. "SDN-based Omni-RAN Use Cases Summary". [Online] <https://mentor.ieee.org/omniran/dcn/13/omniran-13-0044-00-0000-sdn-use-cases-summary.pptx>, May 2013.
11. A. de la Oliva and J. C. Zuniga. "OmniRAN SoA and gap analysis". [Online] <https://mentor.ieee.org/omniran/dcn/13/omniran-13-0038-00-0000-sdn-use-case-gap-analysis.pptx>, May 2013.
12. Juan Carlos Zuniga (InterDigital), Antonio de la Oliva (UC3M), Paul Congdon (Tallac), SDN Use Cases and Requirements, May 2014. <https://mentor.ieee.org/omniran/dcn/14/omniran-14-0041-00-CF00-sdn-use-cases-and-requirements.docx>
13. Antonio de la Oliva (UC3M), Juan Carlos Zuniga (InterDigital), Luis Contreras (Telefonica), Roger Marks (EthAirNet Associates), Generic IEEE 802 Network Reference Model, <https://mentor.ieee.org/omniran/dcn/14/omniran-14-0068-01-CF00-generic-ieee-802-network-reference-model.pptx>

3.1.3 IEEE 802.21d

1. Antonio de la Oliva has been elected as Technical Editor of IEEE 802.21d (IEEE 802.21 Group management), this group is also relevant for CROWD since it is defining handover related signalling for groups of users, which can be used to optimize the handover process in very dense scenarios.
2. Antonio de la Oliva, Yoshikazu Hanatani, Remedy for comment #79, 81, 82, 100, <https://mentor.ieee.org/802.21/dcn/14/21-14-0057-01-MuGM-remedy-for-comment-79-81-82-100.docx>, April 2014 (Revision of contribution made in March)
3. Lily Chen (NIST), Antonio de la Oliva (UC3M), Restructure Cluase 9.4, <https://mentor.ieee.org/802.21/dcn/13/21-13-0227-03-MuGM-restructure-cluase-9-4.docx>, January 2014
4. Antonio de la Oliva (UC3M), Yoshikazu Hanatani (Toshiba), Remedy for comment #79, 81, 82, 100, April 2014. <https://mentor.ieee.org/802.21/dcn/14/21-14-0057-01-MuGM-remedy-for-comment-79-81-82-100.docx>
5. Antonio de la Oliva (UC3M), Remedy comment #83, fig38, April 2014. <https://mentor.ieee.org/802.21/dcn/14/21-14-0071-00-MuGM-remedy-comment-83-fig38.pdf>
6. Antonio de la Oliva (UC3M), Remedy comment #83, fig39, April 2014. <https://mentor.ieee.org/802.21/dcn/14/21-14-0072-00-MuGM-remedy-comment-83-fig39.pdf>

7. Antonio de la Oliva (UC3M), Remedy comment #83, fig41, April 2014. <https://mentor.ieee.org/802.21/dcn/14/21-14-0073-00-MuGM-remedy-comment-83-fig41.pdf>
8. Edition of the IEEE 802.21d/D02 finished on September 2013 (Currently subject of LB7a).
9. Flow diagram specifying operation of CKB method (section 9.4.2 of IEEE 802.21d/D02). <https://mentor.ieee.org/802.21/dcn/13/21-13-0178-01-MuGM-section-9-4-2-flow-char.pdf>, Sept 2013.

3.1.4 IEEE 802 EC Privacy Recommendation Study Group

1. CJ Bernardos, F Giust, A de la Oliva (UC3M), JC Zuniga (InterDigital), WiFi Privacy Experiment at 802 Berlin Plenary, March 2015.
2. Fabio Giust (UC3M), C.J. Bernardos (UC3M) and Antonio de la Oliva (UC3M), MAC experiments and Wiki procedures, Oct 2014.
3. C. J. Bernardos (UC3M), F. Giust (UC3M), A. de la Oliva (UC3M), J.C. Zuniga (InterDigital), WiFi Privacy network experiment at IETF91, January 2015

3.2 Technology transfer

1. Collaboration between AVEA and UC3M is targeted to be transferred into AVEA's network analysis tools. After successful collaboration with UC3M, the trade-offs involved with distributed mobility management techniques have been identified. Initially, further extensive spatio-temporal analysis will be carried out to verify these outcomes. After the end of the project, discussions with the relevant network and Information Technology (IT) departments of AVEA will be held for the proposed distributed mobility management scheme within six months. After the discussions and analysis results are settled down inside the company, the expected deployments of the distributed mobility management solutions are targeted to start within one year in pilot regions.

3.3 New projects

1. VITAL: Virtualized hybrid satellite-Terrestrial systems for resilient and flexible future networks
Budget: 2.9M€, Fudged by: European Commission (EC), H2020-ICT-2014-1 Call
Starting date: 1/2/2015
Partners: CREATE-NET - Center for REsearch And Telecommunication Experimentation for NETworked communities, National Center for Scientific Research Demokritos, Universitat Politcnica de Catalunya, CNES - Centre National dEtudes Spatiales, HSAT - HellasSAT, Intecs SpA, OneAccess SA, Hellenic Telecommunications Organization S.A., Synaptec
Summary: VITAL is project that addresses the combination of Terrestrial and Satellite networks by pursuing two key innovation areas, by bringing Network Functions Virtualization (NFV) into the satellite domain and by enabling Software Defined Network (SDN)-based, federated resources management in hybrid SatCom-terrestrial networks. VITAL will exploit the experience of CROWD as satellite communications are not under the scope of this last. VITAL project will progress beyond the state-of-the-art by investigating in depth the applicability of the SDN-based paradigm to resource management for a combined satellite-terrestrial network.

2. **Xhaul: The 5G integrated fronthaul/backhaul**
Budget: 8M€, Funded by: EC, H2020-ICT-2014-2 Call
Starting date: 1/07/2015
Partners: UC3M (Coordinator), NEC, Ericsson AB, Ericsson TEI, Nokia, ATOS, Interdigital, Telefonica, Telecom Italia, Orange, Visiona, EBlink, NextWorks, Core Network Dynamics, Telnet, FhG-HHI, CTTC, Create-Net, Polito, Lund University and ITRI.
Summary: The Xhaul project aims at developing a 5G integrated backhaul and fronthaul transport network enabling a flexible and software-defined reconfiguration of all networking elements in a multi-tenant and service-oriented unified management environment. The Xhaul transport network envisioned will consist of high-capacity switches and heterogeneous transmission links (e.g., fibre or wireless optics, high-capacity copper, millimeter wave) interconnecting Remote Radio Heads, macro and small cells, cloud-processing units (mini data centres), and points-of-presence of the core networks of one or multiple service providers. This transport network will flexibly interconnect distributed 5G radio access and core network functions, hosted on in-network cloud nodes, through the implementation of: (i) a control infrastructure using a unified, abstract network model for control plane integration; (ii) a unified data plane encompassing innovative high-capacity transmission technologies and novel deterministic-latency switch architectures.
3. **5G-NORMA: 5G NOvel Radio Multiservice adaptive network Architecture**
Budget: 7.9M€, Funded by: EC, H2020-ICT-2014-2 Call
Starting date: 1/07/2015
Partners: NSN Germany, NSN Finland, Alcatel-Lucent Deutschland, Alcatel-Lucent Bell Labs France, NEC Europe Ltd, ATOS, Deutsche Telekom, Orange, Telefonica Investigacion y Desarrollo, Azcom Technology, Nomor Research GmbH, Real Wireless Limited, King's College, Technische Universitaet Kaiserslautern, Universidad Carlos III de Madrid.
Summary: The key objective of 5G NORMA is to develop a conceptually novel, adaptive and future-proof 5G mobile network architecture. The architecture is enabling unprecedented levels of network customisability, ensuring stringent performance, security, cost and energy requirements to be met; as well as providing an API-driven architectural openness, fuelling economic growth through over-the-top innovation. With 5G NORMA, leading players in the mobile ecosystem aim to underpin Europe's leadership position in 5G.
4. **Flex5Gware: Flexible and efficient hardware/software platforms for 5G network elements and devices**
Budget: 8M€, Funded by: EC, H2020-ICT-2014-2 Call
Starting date: 1/07/2015
Partners: INTEL Mobile Communications (Coordinator), ALUD, CEA, CNIT, CTTC, Ericsson AB, F-IAF, iMinds, KU Leuven, NEC, SEQ, Telecom Italia, TST, UC3M, Univ. Pisa, VTT, WINGS.
Summary: The overall objective of Flex5Gware is to deliver highly reconfigurable hardware platforms together with hardware-agnostic software platforms targeting both network elements and devices and taking into account increased capacity, reduced energy footprint, as well as scalability and modularity, to enable a smooth transition from 4G mobile wireless systems to 5G.
5. **5GEx: 5G Exchange**
Budget: 7.92M€, Funded by: EC, H2020-ICT-2014-2 Call
Starting date: 1/10/2015
Partners: Ericsson Magyarorszag Kommunikacios Rendszerek K.F.T. (Coordinator), ATOS Spain SA, Athens University of Economics and Business - Research Center, BISDN GMBH -

Berlin Institute for Software Defined Networks, Budapesti Muszaki ES Gazdasagtudomanyi Egyetem, Deutsche Telekom AG, European Center for Information and communication Technologies GMBH, Ericsson Telecomunicazioni, Hewlett Packard Italiana SRL, Huawei Technologies Dusseldorf GmbH, Kungliga Tekniska Hogskolan, Orange SA, Redzinc Services Limited, Telekom Italia Spa, Telenor Asa, Telefonica Investigacion y Desarrollo Sa, Universidad Carlos III de Madrid, University College London.

Summary: The goal of the 5G Exchange (5GEx) project is to enable cross-domain orchestration of services over multiple administrations or over multi-domain single administrations. This will allow end-to-end network and service elements to mix in multi-vendor, heterogeneous technology and resource environments. Market fragmentation has resulted in a multitude of network operators each focused on different countries and regions. This makes it difficult to create infrastructure services spanning multiple countries, such as virtual connectivity or compute resources, as no single operator has a footprint everywhere.

4 Conclusion

In this deliverable we have summarized the overall achievements of the CROWD project in terms of dissemination and sustainability activities and plans. Ultimately, the CROWD project has developed substantial outcomes including vast amount of scientific publications, significant standardization contributions and several new H2020 projects. Besides creating outstanding outcomes, the CROWD project has resulted in sustainable collaboration among the project partners.