



D4.6 Integration and spreading of excellence results of TREND WP4

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Project Coordinator: Name: Marco Ajmone Marsan
Phone: +39 011 5644032
Fax: +39 011 5644099
e-mail: ajmone@polito.it

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Abstract:

WP4 coordinated the TREND experimental activities, with implementation and testing of the technologies and procedures studied in the other project WPs. This report covers the integration and spreading of excellence within WP4 during the whole duration of the project.

Keyword list: energy efficiency, experiments, measurements, testbeds

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Table of Contents

DISCLAIMER	2
TABLE OF CONTENTS	3
1. EXECUTIVE SUMMARY	4
2. INTRODUCTION	5
3. ADDED VALUE OF THE NOE.....	6
3.1 Integration	6
3.1.1 Experiments on wireless access devices.....	6
3.1.2 Implementation and Measurement of FUFL on the FUB Testbed	6
3.1.3 Measurement and Management of the Energy Cost of Networking Intensive Applications: P2P and OSN	7
3.1.4 Development of the TREND Energy Saving eMulator (TESM).....	7
3.2 Contacts with other projects.....	7
3.3 Contacts with industries	8
3.4 Standardization activities	8
4. BIG PICTURE	9
5. SUMMARY OF THE PAPERS AND MOBILITY ACTIONS.....	10
5.1 Published/submitted papers	10
5.2 Mobility actions	12
6. CONCLUSIONS.....	14
7. REFERENCES.....	15
8. LIST OF ACRONYMS.....	17

1. Executive Summary

This document presents the final report for WP4 of TREND in terms of integration, contacts with other projects, and standardization. TREND is a Network of Excellence (NoE) funded by the Seventh Framework Program of the European Union (FP7/2007-2013) under grant agreement n. 257740. The aim of the NoE is to assess and reduce the energy consumption of telecommunication networks.

The objective of WP4 is the experimental validation and verification of the findings of the other NoE WPs. This implies that WP4 was triggered by the generation of energy efficiency proposals within other WPs, mainly WP2 and WP3, which are chartered with energy efficiency solutions for access and core networks, respectively.

Despite of the slow start of the experimental activities foreseen for WP4, due to the necessary input from other WPs, the last year of the project saw a significant increase of all activities in the WP. Twelve papers were published, and ten mobility actions took place. A large number of Master and PhD students, as well as postdocs, participated in the WP experiments, and acquired significant experience and skills as a result.

Furthermore, contacts with more than ten external projects on network energy efficiency were established, and with more than eleven industrial partners.

Finally, the partners in WP4 participated in twenty one standardization activities.

2. Introduction

The main task of WP4 in TREND was the coordination of experimental activities which were aimed at proving the effectiveness of the approaches proposed in the other technical Work Packages (WP1, WP2, and WP3). As such, WP4 played the role of a hub, whose main achievement in terms of integration was the TREND-Meter tool. The latter concentrated results obtained from different experiment and platforms, thus providing a high-level view of the overall network energy efficiency.

3. Added value of the NOE

Here we show the added value of WP4 in terms of integration, contacts with other projects and industries, and standardization efforts.

3.1 *Integration*

The project started with only one joint activity that was later followed by another one, resulting into joint papers and mobility actions. This also helped to attract collaborating institutions such as IHU, FUB and INRIA. The overall number of papers and mobilities is not very high, but this is due to the much higher complexity and effort required for experimental work. In the last year of TREND the experimental activities have been revised, with the introduction of the following topics:

3.1.1 *Experiments on wireless access devices*

Here the main contributing partners were ALBLF, IHU, UTH, PoliTo, and TUB. The efforts in this activity resulted in 2 papers ([8] and [9]) and 4 mobility actions. Following the mobility actions of TUB, one more article is currently in preparation [12].

Particularly interesting was the joint activity related to the introduction of management algorithms for energy efficiency in the campus network of Politecnico di Torino, over an area devoted to student activities. Results are reported in Section 2 of deliverable D4.5. The very good performance of the algorithms attracted the interest of the network managers at Politecnico di Torino, and a wide-scale deployment of these algorithms for the reduction of the amount of energy necessary to run the WiFi campus network is under consideration. The experiment set-up and execution involved several young researchers, who acquired a significant experience in the measurement and management of energy consumption of private WLANs. One Master student and four postdoc researchers of Politecnico di Torino, as well as one PhD student from TUB and one from iMinds were involved in this activity.

3.1.2 *Implementation and Measurement of FUFL on the FUB Testbed*

The main contributing partners to this activity were TUB, FUB, CNIT and INRIA. The efforts in this activity resulted in 1 paper ([9]) and 2 mobility actions.

The activities within IRA3.1 of WP3 resulted in numerous Energy-Aware Adaptive Routing Solutions (EA-ARSs) (see [13] and the deliverable D3.3 for an overview). One of them gained particular interest of network operators. It is called Fixed Upper Fixed Lower (FUFL). Detailed investigation of FUFL on network scenario forecasts for the year 2020 is presented in [14], which is a joint work of TUB, INRIA, TID and Orange.

A natural step after [14] was to evaluate the FUFL on an experimental testbed. TUB proposed this idea in the Y3, and FUB reported access to a network testbed. Not only FUFL, but also DUFL (Dynamic Upper Fixed Lower) [15] was implemented on the testbed. Results are reported in Section 3 of the deliverable D4.5.

The key outcome of this activity was a demonstration of energy saving on off-the shelf equipment (i.e., routers and Gigabit Ethernet (GbE) line cards). We identified also relatively long times required to access routers in order to perform network reconfiguration. We believe that our work will have impact on development of new generations of routers that will be

dedicated to dynamically activate and deactivate network interfaces (also of higher capacities than GbE). It should be possible to implement local EA-ARs such as FUFL directly on the routers, or decrease the time required to access routers for the EA-ARs such as DUFL.

A PhD student from FUB performed the actual experimental work. He was supported by a PhD student from TUB, two postdocs from FUB and three postdocs from CNIT-UniRoma1.

3.1.3 Measurement and Management of the Energy Cost of Networking Intensive Applications: P2P and OSN

This activity was the former JEA4.1, to which the main contributing partners were CNIT and UC3M. The efforts in this activity resulted in 9 papers ([1], [2], [3], [5], [6], [7], [9], and [10]) and 4 mobility actions.

The outcome of this activity can be considered as a starting point for the development of energy models that could be used to minimize the impact in energy consumption by P2P applications. The obtained results indicate the existence of different scenarios under which the use of P2P has clear advantage over the traditional client-server model; such information could be exploited in helping the design of future energy-aware networks.

During the set-up of the experiment two young researchers have been trained, acquiring a significant experience in experiment design and energy measurement equipment. One associate professor, one assistant professor and one PhD student of UC3M as well as one associate professor, a Post-Doc researcher and one PhD student from CNIT were involved in this activity.

3.1.4 Development of the TREND Energy Saving eMulator (TESM)

Here the main contributing partners were CNIT, INRIA, and TUB. The efforts in this activity resulted in 1 mobility action. Further interaction among the partners is planned in the future, since we have realized that this activity has a strong technical value. In particular, we have built a testbed emulating a network of a telecommunication operator. The testbed is able to run an energy-aware algorithm and to collect the data used by the operator to assess the energy savings and to control the Quality of Service. The testbed will be used as a training infrastructure for the students involved in the telecommunication courses taught by CNIT (University of Rome). As long term impact, the testbed will be enriched by adding more algorithms: thus the testbed will allow to compare the impact of such algorithms on legacy protocols, in terms of control messages generated and QoS performance degradation. The researchers involved in this activity will submit a paper including the comparison of the different algorithms on the testbed. Clearly, the success of the TESSM will include the dissemination of the obtained results on the website, and we plan to add a specific section in the website of the Trend-Meter tool.

3.2 Contacts with other projects

CNIT is the coordinator of the ECONET project, a 3-year IP project (Oct 2010 – Sep 2013) co-funded by the European Commission under the Framework Programme 7 (FP7). Cross-fertilization activities between TREND and ECONET have been constantly carried out by CNIT.

TUB discussed their experimental activities with the partners of DESI project eict GmbH and Zuse Institut Berlin (ZIB). A proposal for collaboration has been made during the

visit of Filip Idzikowski at ZIB (09/01/2013), what resulted in an application of ZIB to become a Collaborating Institution.

TREND has good ties with HOMESNET – the predecessor of the “green” femto has been created within HOMESNET, and invaluable input from this activity has been carried in TREND. HOMESNET was a Celtic-plus (an industry-driven European research initiative) project, which had the objective to develop and to integrate all the elements that are needed to provide Home Base Station (HBS).

Contacts with OPERANET-2 have been created and TREND results have been presented by ALBL-F. OPERA-Net 2 is a Celtic-plus project which aims to reduce the overall environmental impact of mobile radio networks, extending the previous OPERA-Net results.

Both “green” femto and TREND-Meter were presented to GreenTouch in one of the project’s meetings in 2013. GreenTouch is a consortium of leading Information and Communications Technology (ICT) industry, academic and non-governmental research experts dedicated to fundamentally transforming communications and data networks, including the Internet, and significantly reducing the carbon footprint of ICT devices, platforms and networks (<http://www.greentouch.org>).

3.3 *Contacts with industries*

Filip Idzikowski (TUB) visited EICT GmbH on 22/01/2013. TREND WP4 activities and related activities within the DESI project were discussed with FUB, INRIA and CNIT-UniRoma1 in a conf call.

The “green” femto has been presented to several operators during the Bell Labs OpenDays 2012, and also to CMCC during their visit to ALBL-F at the end of 2012.

The WLAN experiments at Politecnico di Torino were made possible by the contacts with CISCO, that provided one router equipped with new energy management capabilities for the execution of the experiments.

3.4 *Standardization activities*

Standardization activities were covered in the corresponding integration deliverables from the Work Packages 1 to 3.

4. Big picture

The largest effort towards the big picture of energy-efficient networking within WP4 is the consolidation of data from different experiments with the help of the TREND-Meter tool.

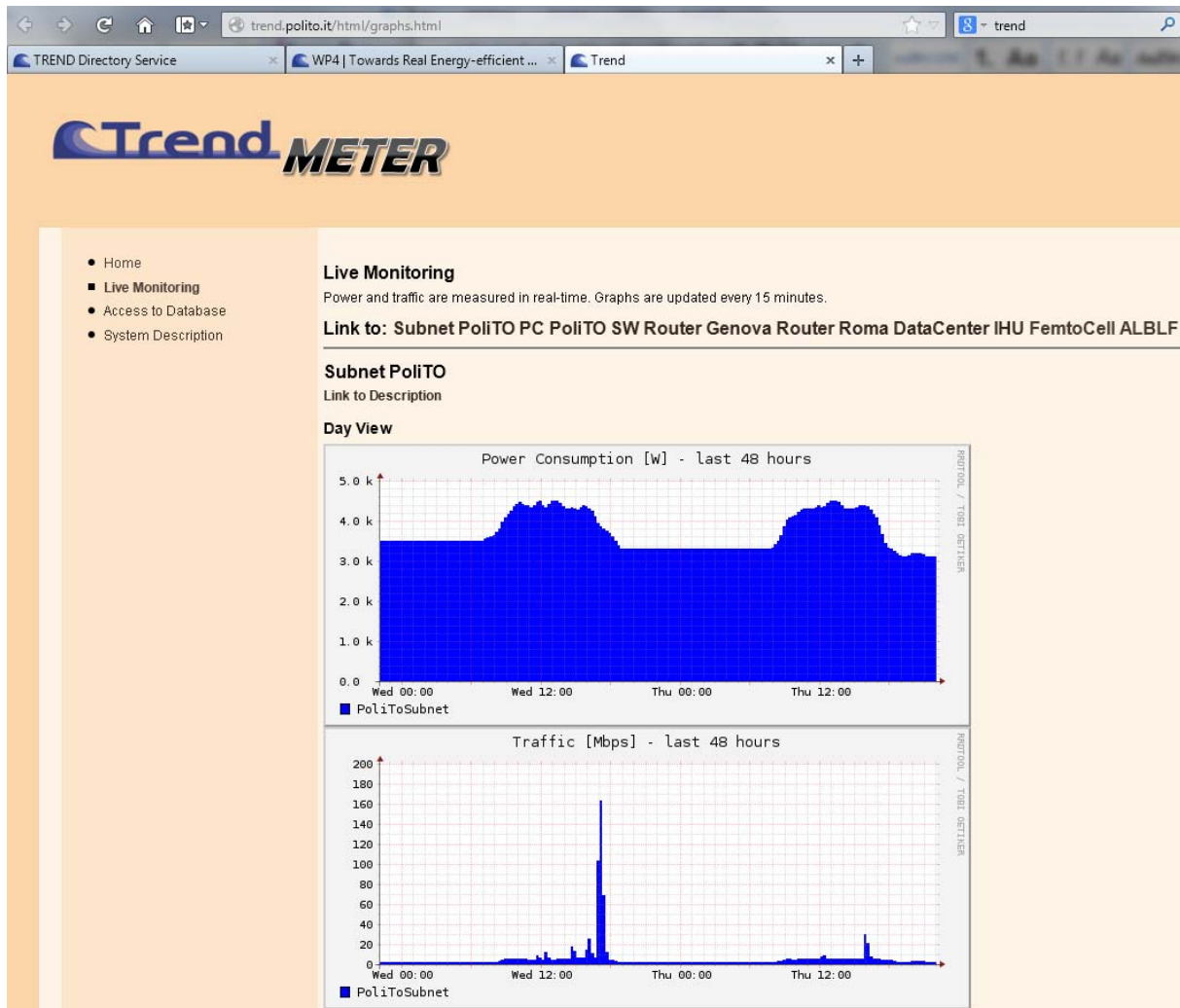


Figure 1: A snapshot of the TREND-Meter online web interface

Another successful achievement that helps unveiling the “big picture” of future “green” networks is the joint paper *The TREND Experimental Activities on “green” Communication Networks*, presented at the 24th Tyrrhenian International Workshop on Digital Communications ([9]).

5. Summary of the papers and mobility actions

5.1 Published/submitted papers

Involved partners/Collaborating Institutions	Authors	Title	Conf/journal	Date of presentation / publication
PoliTo	L. Chiaraviglio, M. Mellia	Energy-Efficient Management of Campus PCs, Green Communications: Theoretical Fundamentals, Algorithms	CRC Press / Taylor & Francis Group	May 2012
UC3M	I. Martinez, R. Gonzalez, C. Guerrero	Validation of H-P2PSIP, a scalable solution for interoperability among different overlay networks	Elsevier Journal on Peer-to-Peer Networking and Applications	July 2012
UC3M, IMDEA Networks	R. Cuevas, M. Kryczka, A. Cuevas, S. Kaune, C. Guerrero, R. Rejae	Unveiling the Incentives for Content Publishing in Popular BitTorrent Portals	IEEE/ACM Transactions on Networking, USA	February 2013
UC3M	R. Cuevas, R. Gonzalez, A. Cuevas, C. Guerrero	Understanding the Locality Effect in Twitter: Measurement and Analysis	Personal and Ubiquitous Computing, USA	February 2013
UC3M, Telefonica Research	R. Cuevas, N. Laoutari, X. Yang, G. Siganos, P. Rodriguez	BitTorrent Locality and Transit Traffic Reduction: when, why and at what cost?	IEEE Transactions on Parallel and Distributed Systems	April 2013

UC3M, University of Oregon	R. Gonzalez, R. Cuevas, R. Motamedi, R. Rejaie, A. Cuevas	Google+ or Google-? Dissecting the Evolution of the New OSN in its First Year	22nd International Worldwide Web Conference WWW 2013, Rio de Janeiro	May 2013
CNIT	R. Bolla, R. Bruschi, O. M. Jaramillo Ortiz, P. Lago	The Energy Consumption of TCP	3 rd ACM/IEEE International Conf. on Future Energy Systems (e-Energy 2013)	May 2013
A-LBLF	I. Haratcherev, A. Conte	Practical energy-saving in 3G femtocells	Workshop on Green Broadband access, pp. 602-606, 2013 IEEE International Conference on Communications Workshops (ICC)	June 2013
CNIT	R. Bolla, R. Bruschi, O. M. Jaramillo Ortiz, R. Rapuzzi	Enabling the TCP Segmentation Offload to Save Energy	24 th Tyrrhenian International Workshop on Digital Communications, Genoa, Italy	September 2013
A-LBLF, PoliTo, TUB, CNIT-Genoa, CNIT- UniRoma1, UC3M, FUB, UTH	I. Haratcherev, M. Meo, Y. Zhang, Y. Hu, A. Conte, F. Idzikowski, Ł. Budzisz, F. Ganji, R. Bolla, O. Jarmilo Ortiz, R. Bruschi, A. Cianfrani, L. Chiaraviglio, A. Coiro, R. Gonzalez, C. Guerrero, E. Tego, F. Matera, S. Keranidis, G. Kazdaridis, and T. Korakis	The TREND Experimental Activities on “green” Communication Networks	24 th Tyrrhenian International Workshop on Digital Communications, Genoa, Italy	September 2013

CNIT, UTH	L. Chiaraviglio, R. Bruschi, A. Cianfrani, O. Jaramillo Ortiz, G. Koutitas	The TREND Meter: Monitoring the Energy Consumption of Networked Devices	International Journal of Business Data Communications and Networking (IJBDCN), IGI Global, special issue on "Green Networking and Computing", Vol. 9, No. 2, pp. 27-44	December 2013
FUB, TUB, CNIT- UniRoma1	E. Tego, F. Idzikowski, L. Chiaraviglio, A. Coiro, and F. Matera	Facing the reality: validation of energy saving mechanisms on a testbed	Journal of Electrical and Computer Engineering	submitted
TUB, PoliTo	F. Ganji, L. Budzisz, F. Debele, N. Li, M. Ricca, Y. Zhang and M. Meo	Greening campus WLANs: energy-relevant usage and mobility patterns	Special Issue on Green Communications, Elsevier Computer Networks	to be submitted

5.2 Mobility actions

Involved partners	Person	Topic	Period
CNIT – UC3M	Olga Maria Jaramillo Ortiz	Experimental activity for measurement and management the energy cost of networking intensive applications: P2P and OSN	22/07/2012 to 29/07/2012
CNIT – UC3M	Roberto Gonzales	Experimental activity for measurement and management the energy cost of networking intensive applications: P2P and OSN	08/07/2012 to 15/07/2012
CNIT – UC3M	Olga Maria Jaramillo Ortiz	Experimental activity for measurement and management the energy cost of networking intensive applications: P2P and OSN	03/06/2013 to 07/06/2013
CNIT – PoliTo	Olga Maria Jaramillo Ortiz	Participation to the TREND PhD School	01/07/2013 to 05/07/2013
CNIT- UniRoma1, TUB	Filip Idzikowski	TESM and FUFL on the FUB testbed (WP3 and WP4)	16/03/2013 to 20/03/2013

PoliTo, TUB	Fatemeh Ganji	Collection of WLAN traces in dense WLAN to verify on/off strategies proposed in WP2 (WP2 and WP4)	21/05/2013 to 31/05/2013
PoliTo, TUB	Fatemeh Ganji	Extraction of usage and mobility patterns of campus WLAN users (WP2 and WP4)	30/06/2013 to 12/07/2013
PoliTo, TUB	Filip Idzikowski	Energy-aware design of IP-over-WDM networks, experimental activities, big picture, and teaching on metro/core networks (WP3 and WP4)	01/07/2013 to 04/07/2013
ALBL-F, PoliTo, IHU	Ivaylo Haratcherev	3G femto delivery, assistance, and introductory course	22/04/2013 to 23/04/2013
ALBL-F, PoliTo	Alberto Conte	Green BS - Architectures and solutions	02/07/2013 to 04/07/2013

6. Conclusions

For the project duration, in total 13 papers were produced in WP4. The statistics regarding those papers are presented in Figure 2.

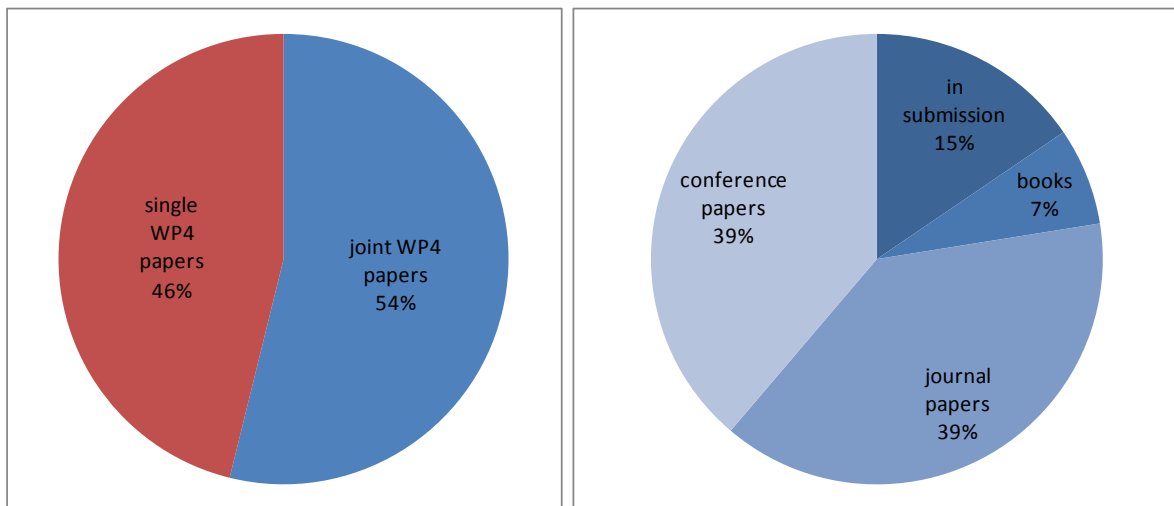


Figure 2: Statistics of papers in WP4 per type

The progress in time for the mobility actions and for the papers in WP4 is shown in Figure 3. While due to the slow start in the first year no actions and papers were produced, in the following years there was a huge increase.

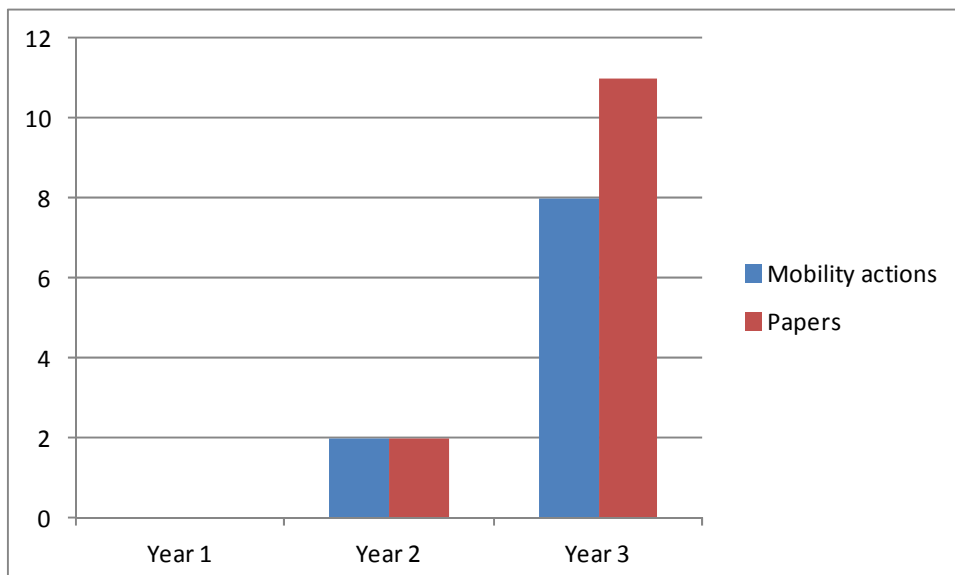


Figure 3: Statistics of mobility actions and papers in WP4 per year

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Papers from WP4

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Papers from other WPs

- [13] F. Idzikowski, E. Bonetto, L. Chiaraviglio, A. Cianfrani, A. Coiro, R. Duque, F. Jiménez, E. Le Rouzic, F. Musumeci, W. Van Heddeghem, J. López Vizcaíno, and Y. Ye, "TREND in Energy-Aware Adaptive Routing Solutions," IEEE Communications Magazine, vol. 51, no. 11, November 2013
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8. List of Acronyms

DUFL	Dynamic Upper Fixed Lower
EA-ARS	Energy-Aware Adaptive Routing Solution
FUFL	Fixed Upper Fixed Lower
GbE	Gigabit Ethernet
HBS	Home Base Station
ICT	Information and communication technologies
IRA	Integrated Research Activity
WP	Work Package