D2.7 Integration and spreading of excellence results within TREND WP2

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Abstract:

Integration and spreading of excellence is presented for Work Package 2 on Access Networks. Factual results in terms of collaboration within and outside TREND are detailed. Big picture results produced by the Work Package are also shown.

Keyword list:

General keywords: Dissemination, integration, standardization, education

Technical keywords: Resource allocation, algorithms for base station management in cellular networks, self optimized energy-efficient networks, renewable energy sources and telecommunication networks, smart-grids, access networks, energy-efficient hardware equipment, energy measurements from ICT equipment

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1. Executive Summary

This deliverable presents the outcome of the Work Package 2 of the TREND project in terms of integration, contacts with other projects, and standardization. It gives an overview of the collaboration that was achieved during the three years of the project on access networks and briefly summarizes the big picture studies that have allowed putting the technical achievements of the Work Package into a broader perspective.

2. Introduction

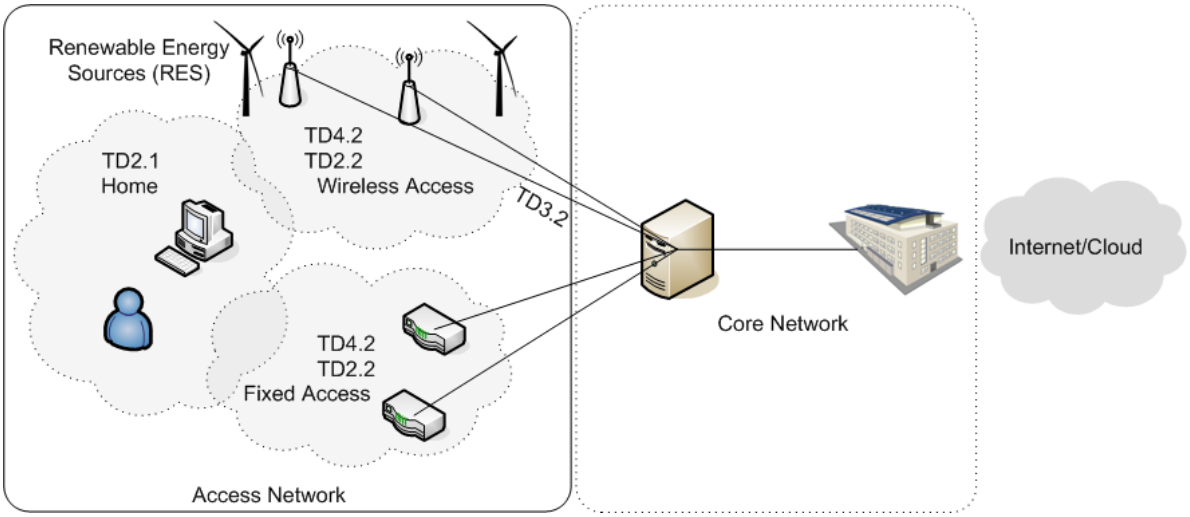

Figure 1 – Network Access and domains studied within TREND. The frame represents the segment covered in this paper.

The access part of modern cellular systems is the most energy demanding part of the network. It incorporates network nodes, such as base stations (macrocells, microcells, picocells and femtocells), as well as access points, such as DSL routers and WiFi APs, as shown in Figure 1. Despite the fact that the power needs and energy consumption of the individual nodes is small, their large number in the network yields to enormous energy demands.

The need for high data rates (5G networks) and large data volumes from non-human centric data (Advanced Metering Infrastructures-AMI and Internet of Things-IoT) that are expected in the future, will drive the number of access nodes and thus their aggregated energy consumption to enormous values. This condition has a direct effect on the OPEX of the operator and the cost of services. Within WP2, TREND has focused on the development of sophisticated solutions and techniques that enable energy saving in the access network or even cooperation with renewable energy sources (RES) to reduce the costs and energy waste of the sector. In the introductory part of the report, WP2 presents a map of the most critical points of interest as well as the main achievements in terms of energy saving.

Power Consumption of Modern Networks and Network Nodes

Modern cellular networks suffer from great energy waste, especially during off-peak hours, when data traffic is low, because the network equipment power consumption presents small sensitivity with respect to network traffic. One important issue that has attracted the concern of regulatory and standardization bodies such as 3GPP and IEEE is to increase the traffic-proportional network power consumption characteristics.

The reason behind the great energy waste (especially during off-peak hours) is that telecommunication nodes (BSs, APs, Femtocells) incorporate two types of losses. The no-load losses (parameter b of the equation below) and the IT losses. No-load losses exist even when there is no traffic served by the IT equipment. No-load losses account for a great portion of the total power consumption of the node and are usually related to network critical physical infrastructure (NCPI), such as cooling and power units, fans, etc. This has the consequence of great amounts of energy wasted during off-peak hours, and thus it is important to switch off unnecessary nodes in the network in order to save energy and provide

traffic-proportional network power consumption. A typical dependency of BS or AP power consumption with traffic is given in Figure 2.

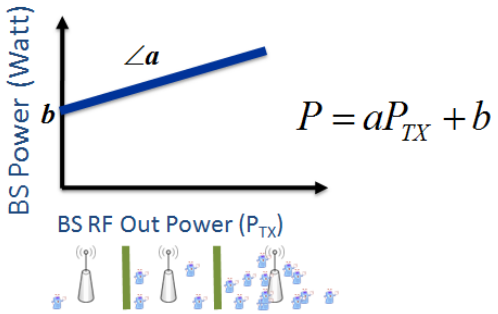

Figure 2. Power consumption versus RF out power of typical BSs and APs

On the other hand, network traffic presents a high daily variation that in some occasions can yield to traffic variations during the day with peak-to-average ratio greater than 3. This is also met in business districts where traffic during the day can be more than 7 times larger than traffic during the night. Unfortunately, network power consumption does not present such a high correlation with traffic due to the existence of no-load losses and low proportionality characteristics in the hardware of the network nodes. One approach to overcome this situation is to provide switch on/off schemes at the network nodes when necessary, and thus 'force' a higher proportionality with traffic, as shown in Figure 3.

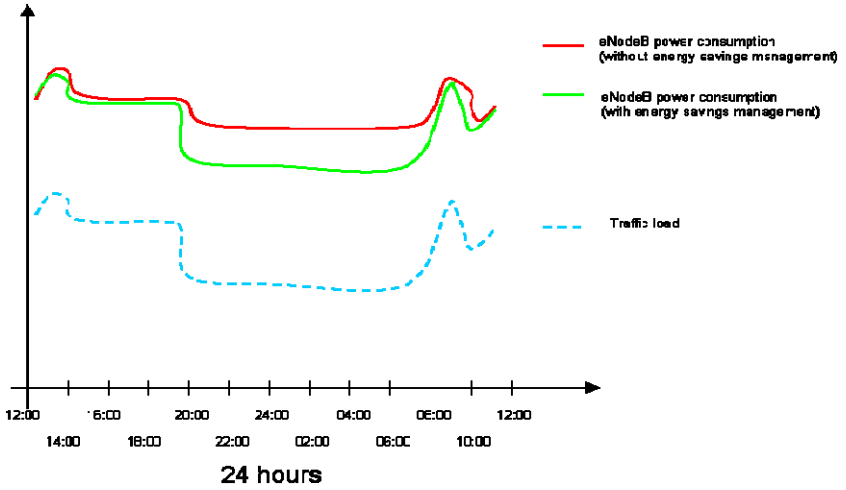

Figure 3. Traffic variation and eNodeB power consumption with and without energy saving modes based on 3GPP.

The Future Internet Characteristics

The future Internet must be a smart network that is flexible, robust and cost effective. This is included in the 5G infrastructure report, that was recently published as a joint academic and industrial guideline. Much research interest is presently focusing upon energy-efficient networking techniques, green Service Level Agreements (SLAs) and penetration of RES (renewable energy sources) in the network that offer free energy that can fulfill the cost-effective characteristic of the future Internet. The flexibility refers to adaptation to external conditions and also support of different types of data (low data rate for M2M communications, and high data rates for UHDTV).

Focusing on the cost-effective part, and more precisely on the operational expenses (OPEX) of the network, which is mainly related to energy consumption, it is expected to observe in the 5G network a saving up to 90% with respect to the situation of today, per unit of service provided. The most important already existing technologies to support such a radical reduction are: base station switch on/off schemes that are already incorporated in 3GPP plans, multipath TCP and multi RAT access that provide resource management-offloading, task migration and allocation strategies over virtualization schemes and green SLAs that can provide adaptable network operation.

Furthermore, the external conditions that characterize the flexible operation of 5G networks can be context-based, traffic-based, or even characterized by the available energy that is supplied by the power grid network. This is discussed in the next section.

The Future Energy Issues

Together with the need for energy saving during off-peak hours, there is one more important characteristic that needs to be considered in future networks. It is becoming a global trend to install off-grid BSs, or even to power a subset of the network with renewable energy sources (RES). The main constraint of RES is that they provide a limited and time variant power capacity that should not be exceeded if the network must operate in island mode (net-zero operation with no import of energy). To achieve this target, it is important that the telecommunication network operator has the ability to provide load (power) control in the network.

Furthermore, with the development of smart grids, and the open/competitive energy market that will support real time (dynamic) electricity pricing schemes, the network should be able to support load control and demand response (DR) commands in order to reduce consumption during high electricity price hours. In the case, cooperation and offloading to other networks (WiFi or femtocells) is of major importance. Adaptation to real time electricity signals is also important for the cost effective characteristic of the future Internet

In this Work Package (WP) we focus on access networks, including wireless as well as wired access. The main contribution of TREND is to provide the necessary tools and technologies for the management of the network nodes towards energy savings, the integration of the network nodes with the energy sector for supporting RES and net-zero operation. Furthermore, smart-grid based solutions were developed, and these were coupled with technologies in the telecommunication sector to provide new insights for smart telecommunication networks.

This document describes the measurable results obtained by the WP in terms of integration, dissemination and spreading of excellence. It completes a more technical report (D2.6) where detailed descriptions of the technical achievements of partners and collaborating institutions has been provided.

The partners that contributed to this document are listed below:

Partner short name
PoliTO
EPFL
A-LBLF
UC3M
IMINDS
TID
TUB
IMDEA
UTH
FT
TUD
CNIT
INRIA
IHU

3. Added value of the NOE

This section shows the added value of the WP2 of TREND in terms of integration, contacts with other projects and industries, standardization.

3.1 Integration

The project started with clearly identified joint activities that resulted into a high number of joint papers and mobility actions. This also helped to attract collaborating institutions such as IHU, INRIA, TUD, IMDEA. During the three years of WP2, all of the partners and collaborating institutions of WP2 had at least one mobility action or participation in a joint paper.

The most important joint work of WP2 falls in the following domains

3.1.1 BS and AP Switch on/off Algorithms

This is a big part of WP2 since it gives a holistic overview of the problem of network nodes management. The investigation focused on BSs and APs. This work was part of the IRA 2.2 of WP2 of TREND. The investigation commenced by the work of PoliTO and contintues with UTH, IHU, TUB, iMINDS, EPFL, ALBLF, TID, IMDEA. Within this activity, WP2 presented switch on/off techniques that can collaborate with other heterogeneous networks (WiFi or femtocell) and thus enable load migration and adaptable power consumption at the administrative domain of the mobile operator when necessary (during high traffic hours too). The presented techniques cover BS, AP and femtocell networks and provide acceptable QoS with an important reduction of energy and power when necessary.

The aggregated results covering the major aspects of specialization and papers of TREND partners are incorporated in the following review type papers. In total there were approximately 20 (25%) joint papers in the this area and 10 mobility actions (48%).

- Y. Zhang (PoliTO), L. Budzisz (TUB), M. Meo (PoliTO), A. Conte (A-LBLF), I. Haratcherev (A-LBLF), G. Koutitas (UTH), L. Tassiulas (UTH), M. A. Marsan (PoliTO), S. Lambert (iMinds), An Overview of Energy-efficient Base Station Management Techniques, 24th Tyrrhenian International Workshop on Digital Communications (TIWDC'13), Genoa, Italy, September 2013

- L. Budzisz (TUB), Ganji Fatemeh, G. Rizzo, B. Lanoo, Mario Pickavet, Y. Zhang (PoliTO), M. Meo (PoliTO), A. Conte (A-LBLF), I. Haratcherev (A-LBLF), G. Koutitas (UTH), L. Tassiulas (UTH), M. A. Marsan (PoliTO), S. Lambert (iMinds), 'Dynamic Resource Provisioning for Energy Efficiency in Wireless Access Networks: a Survey and an Outlook', IEEE Communications Surveys and Tutorials, under review (second round), 2013

3.1.2 Mobile Network Operators Cooperation

This work is based on algorithms derived from the BS switch on/off algorithms and started in the last year of the project. The work was based on a paper that was first introduced

by PoliTO and is continued with the contribution of UTH, IHU, iMINDS, TUB. One joint paper is under submission; it covers all aspects of cooperation between MNOs. This includes non-cooperative and cooperative game theoretic approaches. One paper is under preparation:

- G. Koutitas (UTH), G. Iossifidis (UTH), B. Lanoo (iMINDS), M. Tahon (iMINDS), S. Verbrugge (iMINDS), P. Ziridis (IHU), L. Budzisz (TUB), M. Meo (PoliTO), M. Marsan (PoliTO), L. Tassiulas (UTH), A Game Theoretic Approach for Mobile Network Operators Cooperation, to be submitted Journal, 2013

3.1.3 Home equipment management

This work was part of IRA 2.1. It approached the problem of energy management of home equipment. In this field there were two different threads. One concerned the case of the development of a 3G-femtocell prototype that can support on/off schemes. The other direction of the investigation concerned the development of smart-grid algorithms for energy management of connected home appliances (demand response solutions). The integration of work includes partners such as UTH, IHU, ALBLF, TID. There was one prototype developed and one patent application. The most important publications in this area are

- Haratcherev, A. Conte, "Practical energy efficiency in 3G femtocells"- International Conference INFOCOM, 2013
- Patent Application P201130693
- Iordanis Koutsopoulos and Leandros Tassiulas, 'Challenges in demand load control for the smart grid', IEEE Networks, vol. 15, no. 5, 2011
- I. Koutsopoulos and L. Tassiulas, 'Optimal control policies for power demand scheduling in the smart grid', IEEE Selected Areas on Communic., vol. 30, no.6 ,pp. 1049-1060, 2012
- G. Koutitas, Control of Flexible Smart Devices in the Smart Grid, IEEE Transactions Smart Grids, Vol. 3, No. 3, pp. 1333- 1343, September 2012
- G. Koutitas, L. Tassiulas, Periodic Flexible Demand: Optimization and Phase Management in the Smart Grid, IEEE Transactions Smart Grids, Vol. 4, No. 3, pp. 1305- 1313, September 2013

3.1.4 Physical layer techniques

This work was based on activities that the majority of TREND partners were involved at the beginning of the TREND project. It concerned the development of energy-efficient techniques that are applied at the physical layer of the system, focusing on the wireless transmission medium (OFDM, CDMA, relay systems, MIMO, etc.). There were more than 20 papers published in this domain and some characteristic examples are:

- Zappone (TUD), G. Alfano (PoliTO), S. Buzzi (CNIT), M. Meo (PoliTO), Distributed energy-aware resource allocation in multi-antenna multi-carrier interference networks with statistical CSI, EURASIP Journal on Wireless Communications and Networking, Vol. 2013, to be published

- A. Lombardo (CNIT), C. Panarello (CNIT), G. Schembra (CNIT), EE-ARQ: a Green ARQ-Based Algorithm for the Transmission of Video Streams on Noise Wireless Channels, Network Protocols and Algorithms, Vol. 5, No. 1, March 2013
- S. Buzzi (CNIT), G. Colavolpe (University of Parma), D. Saturnino (Scuola Sant'Anna di Pisa), A. Zappone (CNIT), Potential Games for Energy-Efficient Power Control and Subcarrier Allocation in Uplink Multicell OFDMA Systems, IEEE Journal of Selected Topics in Signal Processing, Vol. 6, No. 2, pp. 89 - 103, USA, April 2012
- A. Zappone and E. Jorswieck, "Resource Allocation in Amplify-and-Forward Relay-Assisted DS/CDMA Channels," IEEE Transactions on Wireless Communications, Vol. 11, pp. 1271-1276, April 2012

3.1.5 Joint activities across multiple workpackages

During the three years of TREND, WP2 has integrated its own research with other WPs such as WP1, WP3 and WP4. More precisely, for WP1 there has been joint research on modelling energy consumption in different parts of the access network and also investigation of mobile network cooperation. For WP3 there has been a joint work on integration of RES with servers/data centers of the network. Finally, there was an integrated work with WP4 in the area of measurements of energy efficiency and power consumption of network equipment and collection of mobility patterns of WLAN users to feed on/off switching algorithms (activity 1 in WP4) between TUB and PoliTO. Some characteristic examples are:

- D. Hatzopoulos (UTH), I. Koutsopoulos (UTH), G. Koutitas (UTH), W. Van Heddeghem (iMinds), Dynamic Virtual Machine Allocation in Cloud Server Facility Systems with Renewable Energy Sources, ICC 2013, Budapest, Hungary, to be published. (WP2 WP3)
- E. Le Rouzic (Orange), E. Bonetto (PoliTO), L. Chiaraviglio (INRIA), F. Giroire (INRIA), F. Idzikowski (TUB), F. Jiménez (TID), C. Lange (DT), J. Montalvo (TID), F. Musumeci (CNIT), I. Tahiri (INRIA), A. Valenti (FUB), W. Van Heddeghem (iMinds), Y. Ye (HWDU), A. Bianco (PoliTO), A. Pattavina (CNIT), TREND towards more energy-efficient optical networks, Optical Network Design and Modelling, Invited, Brest, France, April 2013. (WP2 WP3 WP1)
- K. Verma (IMDEA), G. Rizzo (IMDEA), A. Fernandez-Anta (IMDEA), R. Cuevas-Rumin (UC3M), A. Azcorra (UC3M), Greening the Internet: Energy-Optimal File Distribution, 2012 IEEE 11th International Symposium on Network Computing and Applications, August 2012. (WP3 WP2)
- L. Chiaraviglio, R. Bruschi, A. Cianfrani, O. M. Jaramillo Ortiz, G. Koutitas, 'The TREND Meter: Monitoring the energy consumption of networked devices', Int. Journal of Business Data Communications and Networking (IJBDCN), IGI Global, special issue on 'Green Networking and Computing', 2013 (WP2-WP4)
- S. Wiethölter, M. Emmelmann, R. Andersson, and A. Wolisz, "On the analysis of WiFi communication and WiMAX network entry over single radios", in the Proc. of CONWIRE workshop (co-located with IEEE ICC conference), Ottawa, Canada, June 2012 (WP1-WP2)
- K. Verma (IMDEA), G. Rizzo (IMDEA), A. Fernandez-Anta (IMDEA), R. Cuevas-Rumin (UC3M), A. Azcorra (UC3M), Greening the Internet: Energy-Optimal File

Distribution, 2012 IEEE 11th International Symposium on Network Computing and Applications, August 2012 (WP1-WP2)

- G. Koutitas (UTH), G. Iossifidis (UTH), B. Lanoo (iMINDS), M. Tahon (iMINDS), S. Verbrugge (iMINDS), P. Ziridis (IHU), L. Budzisz (TUB), M. Meo (PoliTO), M. Marsan (PoliTO), L. Tassiulas (UTH), A Game Theoretic Approach for Mobile Network Operators Cooperation, to be submitted Journal, 2013 (WP1-WP2)

3.2 Contacts with other projects

TREND partners have established contacts with other collaborative projects (initiatives, European FP7 projects) as a means of fostering the dissemination of TREND results within the research community and starting collaboration between projects on related topics. The most important collaborations were with:

GreenTouch consortium, **ECONET**, **EARTH, GREENNET**: The partners presented WP2 activities and collaborated in the organization of common workshops and exchange of information and ideas.

3.3 Contacts with industries

TREND and WP2 of TREND created synergies with industry. This was actually the main target of the TREND Industrial Conference held in the context of e-Energy 2012 in Madrid. Furtermore, there was some other publications with industries such as:

UTH worked with AirCom (UK) and published one paper

- G. Koutitas, A. Karousos, L. Tassiulas, 'Deployment Strategies and Energy Efficiency of Cellular Networks', IEEE Transactions on Wireless Communications, vol. 7, no.11, pp. 2252-2563, 2012

3.4 Educational Perspectives

WP2 TREND concepts are integrated in various educational activities. A TREND PhD school was organized at PoliTO in 2013 focusing on all aspects of the project, including WP2. This course will be repeated in 2014, and is likely to become a stable offering for PhD students. In addition, an MSc level module entitled "Green ICT" was established, based on the joint activities of PoliTO, UTH and IHU. The module covers energy efficiency in wired and wireless networks, emphasizing the domain of wireless access. In addition, there was a seminar for Electronic Advanced System Master Students at UC3M, a performance evaluation course and a throughput and Power Consumption Lab at EPFL. Furthermore, there were approximately 85 talks-seminars by WP2 TREND partners.

3.5 Participation in a new Proposal

TREND partners have collaborated towards the submission of new research proposals that are associated to the activities of WP2. More precisely there were two strong collaborations over the three years. These are

Marie Curie (ITN)-DARE Proposal: In 2012 UTH, IHU, PoliTO, IMDEA, EPFL, UC3M, ALBLF, TUB which are TREND WP2 partners together with external partners (both academia and industry) such as Univ. Southampton, Toshiba Research Europe, Univ. Gent, Secure Meters Limited, Iquadrat Informatica S.L., Sistemas Avazandos de Technologia and ITU (International Telecommunication Union) submitted the proposal DARE (Demand Response in Smart Data and Power Networks). The proposal aims to couple power networks and data networks under the umbrella of demand response.

COST Action-Sustainable Networking Proposal: In 2012 WP2 TREND partners collaborated and submitted a COST proposal entitled as Sustainable Networking. The scope of the proposal is to increase networking in Europe in this direction and investigate future paths of Energy Efficient Networking.

3.6 Standardization activities

WP2 TREND partners collaborated with standardization bodies and participated in the development of standards. The collaboration concerned the following bodies: ETSI, 3GPP, IETF, ITU-T. In general there were 18 activities regarding standards mainly from TUB, Orange, TID, ALBLF and PoliTO. More details are available in the WP5 deliverable.

4. Big picture

One important result of the WP2 activities has been the elaboration of the big picture of energy efficiency in access networks, leveraging the work of several partners. Over the last three years, the WP2 of TREND was trying to establish the following operational strategy.

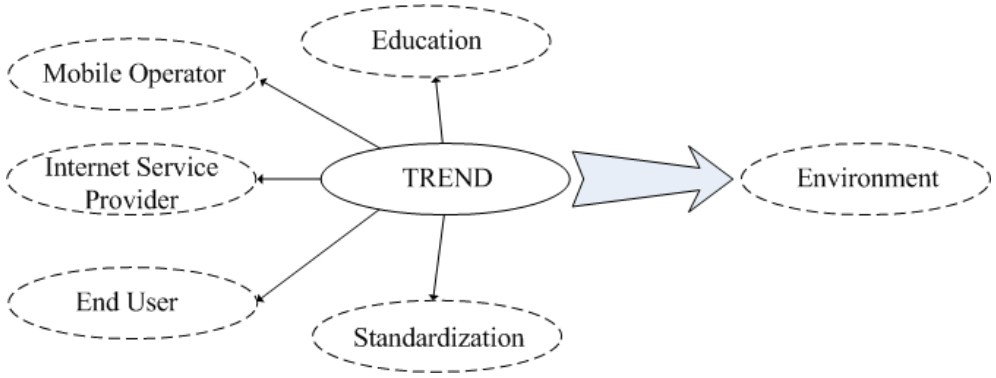

Figure 4. Power consumption versus RF out power of typical BSs

The general objective of the strategy consists in providing benefits to third parties, that translate into protection of the environment.

The general operation of WP2 key results are exposed below

4.1 Consolidating power consumption values (joint activity with WP1)

Partners of WP2 have provided data to Powerlib, a database containing consistent data regarding the power consumption of network elements. Despite the fact that the majoirity of data concern core network equipment, the same WP2 partners have provided data for the access network. These are included in the http://powerlib.intec.ugent.be/ website **powerlib.**

4.2 Mapping energy savings of the access network

WP2 provided a mapping of possible (expected) energy savings achievable by implementing the proposed technologies and schemes. The aggregated presentation of the findings is based on the collaborative work of WP2 partners. These are shown in the figure below.

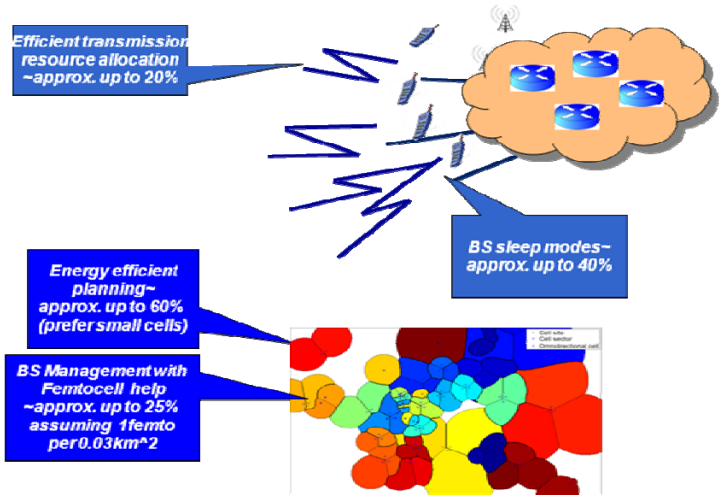

Figure 5. Expected energy savings from WP2 technologies

The aforementioned areas can be summarized in the following tables that give the aggregated findings and the beneficiaries of WP2 TREND.

Table 1. WP2 Mapping of Achievements

Technical Domain	**Network Map**	**Main Topics of Interest**	**Energy Savings**
TD2.1	Home and wireless access	• Prototype 3G WiFi femtocell with sleep modes • Femtocell management schemes • Smart grid algorithms for energy savings at home appliances	• Approx. 70% according to user activity in the house • Approx. 20% • Approx. 20%
TD2.2	Wireless and fixed access	• NGPON network power consumption analysis • Residential gateway virtualization for energy savings • Multipath TCP energy savings and offloading • Energy Consumption in File/Content Distribution Processes	• Depends on architecture. Approx. 10% • The energy that is saved is equal to the difference in energy consumption when a user is served by LTE base station and when he is served by WiFi base station.
TD2.3	Wireless and Fixed access	• Resource allocation MIMO • Resource allocation in relay assisted networks • Resource allocation in OFDM networks • Energy-Efficient QoS-constrained ARQ protocols	• Up to 20% • Up to 20% • Up to 20% • Up to 10%
TD 2.4	Wireless Access	• Energy efficient network planning	• Approx. 60% (prefer small cells)

		• Base station and access point switch on/off schemes	• Up to 40% and extra 25% if offloading to femtocell layer is used
		• Integration with renewable energy sources	• Theoretical net zero operation
		• MNO cooperation	• Up to 40%

Table 2. Beneficiaries of WP2 TREND

Name of Beneficiary	**WP2 TREND Result**
End User	• Developed a WiFi-3G femtocell prototype that incorporates sleep modes • Developed solutions to manage WiFi Access Points and femtocells • Developed smart grid (demand response) algorithms to manage energy at households • Multipath TCP for offloading
Mobile Operator	• Developed startegies for energy efficient planning of BSs • Developed BS on/off schemes (centralized, distributed, pseudo-distributed) • Energy efficient transmission techinques (MIMO, power control, OFDM) • Cooperation schemes for relay networks • Multipath TCP for offloading • Autonomous networking including RES and BS operation
Internet Provider	• Developed resource management algorithms in internet nodes • Developed techniques to reduce the number of Optical Line Terminals (OLTs) equipment • Developed theoretical approximations to allocate power consumption to file/content distribution processes

4.3 Management of Network Elements

Within WP2 of TREND a research thread focused in the area of management of network elements. The investigation concerned BSs, APs and femtocells. The key directions behind this effort was to establish applicable solutions for nodes management, such as:

- Provide energy savings in the network and traffic proportional power consumption
- Enable an easy integration of RES into a network capable of supporting demand response signals
- Enable operators to cooperate and share their access network infrastructures.

WP2 partners PoliTO, UTH, IHU, TUB, iMINDS, ALBLF, IMDEA, INRIA, CNIT, worked in this direction to give a holistic approach to the aforementioned problems. The following papers constitute the most generic cases of the investigation.

- Y. Zhang (PoliTO), L. Budzisz (TUB), M. Meo (PoliTO), A. Conte (A-LBLF), I. Haratcherev (A-LBLF), G. Koutitas (UTH), L. Tassiulas (UTH), M. A. Marsan (PoliTO), S. Lambert (iMinds), An Overview of Energy-efficient Base Station Management Techniques, 24th Tyrrhenian International Workshop on Digital Communications (TIWDC'13), Genoa, Italy, September 2013
- L. Budzisz (TUB), Ganji Fatemeh, G. Rizzo, B. Lanoo, Mario Pickavet, Y. Zhang (PoliTO), M. Meo (PoliTO), A. Conte (A-LBLF), I. Haratcherev (A-LBLF), G. Koutitas (UTH), L. Tassiulas (UTH), M. A. Marsan (PoliTO), S. Lambert (iMinds), 'Dynamic Resource Provisioning for Energy Efficiency in Wireless Access Networks: a Survey and an Outlook', IEEE Communications Surveys and Tutorials, under second review stage (major corrections), 2013
- G. Koutitas (UTH), G. Iossifidis (UTH), B. Lanoo (iMINDS), M. Tahon (iMINDS), S. Verbrugge (iMINDS), P. Ziridis (IHU), L. Budzisz (TUB), M. Meo (PoliTO), M. Marsan (PoliTO), L. Tassiulas (UTH), A Game Theoretic Approach for Mobile Network Operators Cooperation, to be submitted Journal, 2013
- G. Koutitas (IHU), L. Tassiulas (UTH), Smart Grid Technologies for Future Radio and Data Centre Networks, IEEE Communications Magazine, Vol. in press, No. in press, to be published.

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
CNIT	A. Lombardo (CNIT), C. Panarello (CNIT), G. Schembra (CNIT),	*Analytically Evaluating the Impact of Wireless Channel Behavior on an Energy-Efficient Rate-Controlled Video Transmission System*	Conf SustainIT 2013	Oct. 2013
CNIT	A. Lombardo (CNIT), V. Riccobene (CNIT), G. Schembra (CNIT)	*Designing a Governor Policy for Energy Saving and Heat Control in Frequency-Scaling Green Routers*	Conf IEEE online Greencomm 2013	Oct. 2013
CNIT/TUD	L. Venturino (CNIT), C. Risi (CNIT), A. Zappone (TUD), S. Buzzi (CNIT),	*Energy efficient coordinated user scheduling and power control in downlink multicell ofdma networks*,	Conf Proceedings of PIMRC 2013	Sept 2013
iMINDS, TID	S. Lambert (iMinds), J. Montalvo (TID), J. Torrijos (TID), B. Lanoo (iMinds), D. Colle (iMinds), M. Pickavet (iMinds),	*Energy Demand of High-Speed Connectivity Services in NG-PON Massive Deployments*	Conf 39th European Conference and Exhibition on Optical Communication (ECOC 2013)	Sept 2013
TUB	F. Ganji (TUB), L. Budzisz (TUB), A. Wolisz (TUB)	*Assessment of the Power Saving Potential in Dense Enterprise WLANs*	Conf 24th annual IEEE Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'13)	Sept 2013

PoliTO, TUB, ALBLF, UTH, iMINDS	Y. Zhang (PoliTO), L. Budzisz (TUB), M. Meo (PoliTO), A. Conte (A-LBLF), I. Haratcherev (A-LBLF), G. Koutitas (UTH), L. Tassiulas (UTH), M. A. Marsan (PoliTO), S. Lambert (iMinds)	*An Overview of Energy-efficient Base Station Management Techniques*	Conf 24th Tyrrhenian International Workshop on Digital Communications (TIWDC'13)	Sept 2013
UTH	G. Koutitas (UTH), L. Tassiulas (UTH),	*Periodic Flexible Demand: Optimization and Phase Management in the Smart Grid*	Journal IEEE Transactions Smart Grids, Vol. 4, No. 3, pp. 1305 - 1313	Sept 2013
TUD, CNIT, PoliTO	A. Zappone (TUD), S. Buzzi (CNIT), E. Jorswieck (TUD), M. Meo (PoliTO)	*A survey on game-theoretic approaches to energy-efficient relay-assisted communications*	Conf Proc. of the 24th Tyrrhenian International Workshop on Digital Communications (TIWDC 2013)	Sept 2013
iMINDS, TID, ALBLF	S. Lambert (iMinds), B. Lannoo (iMinds), D. Colle (iMinds), M. Pickavet (iMinds), J. Montalvo (TID), J. Torrijos (TID), P. Vetter (ALBLF)	*Power Consumption Evaluation for Next-Generation Passive Optical Networks*	Conf 24th Tyrrhenian International Workshop on Digital Communications (TIWDC '13)	Sept 2013
iMINDS, TID,	S. Lambert (iMinds), J. Montalvo (TID), J. Torrijos (TID), B. Lanoo (iMinds), D. Colle (iMinds), M. Pickavet (iMinds)	*Energy efficiency analysis of NGPON technologies in a massive deployment*	Conf International Conference on Transparent Optical Networks (ICTON 2013)	June 2013
CNIT, TUD	S. Buzzi (CNIT), A. Zappone (TUD)	*Potential games for energy-efficient resource allocation in multipoint-to-multipoint CDMA wireless data networks*	Journal Physical Communication, Vol. 7, pp. 1 - 13	June 2013
TUD, CNIT	A. Zappone (TUD), E. Jorswieck (TUD), S. Buzzi (CNIT)	*Competitive Energy-Aware Power Control in Relay-Assisted Interference Channels Considering Circuit Dissipated Power*	Conf IEEE 77th Vehicular Technology Conference	June 2013

CNIT	R. Bruschi (CNIT), A. Lombardo (CNIT), C. Panarello (CNIT), F. Podda (CNIT), E. Santagati (CNIT), G. Schembra (CNIT)	*Active Window Management: Reducing Energy Consumption of TCP Congestion Control*	Conf IEEE ICC 2013	June 2013
FT, PoliTO, INRIA, TUB, TID, CNIT, FUB, iMINDS, HWDU,	E. Le Rouzic (Orange), E. Bonetto (PoliTO), L. Chiaraviglio (INRIA), F. Giroire (INRIA), F. Idzikowski (TUB), F. Jiménez (TID), C. Lange (DT), J. Montalvo (TID), F. Musumeci (CNIT), I. Tahiri (INRIA), A. Valenti (FUB), W. Van Heddeghem (iMinds), Y. Ye (HWDU), A. Bianco (PoliTO), A. Pattavina (CNIT),	*TREND towards more energy-efficient optical networks*	Journal Optical Network Design and Modelling	April 2013
TUD, CNIT	A. Zappone (TUD), Z. Chong (TUD), E. Jorswieck (TUD), S. Buzzi (CNIT),	*Energy-aware competitive power control in relay-assisted interference wireless networks*,	Journal IEEE Transactions on Wireless Communications, Vol. 12, pp. 1860 - 1861	April 2013
CNIT	D. Reforgiato (CNIT), V. Riccobene (CNIT)	*FREE - Fast Reroute for Energy Efficiency*	Conf IEEE Infocom 2013	April 2013
TUB	F. Ganji (TUB), L. Budzisz (TUB), A. Wolisz (TUB)	*Assessment of the Power Saving Potential in Dense Enterprise WLANs*	Tech. Report TKN Technical Report Series, Berlin	April 2013
FT, Telecom Paris Tech	Q. Deniel (Orange), F. Saliou (Orange), P. Chanclou (Orange), D. Erasme (Telecom ParisTech)	*elf-Seeded RSOA based WDM-PON Transmission Capacities*	Conf Optical Fiber Communication Conference and Exposition OFC/NFOEC 2013	March 2013
EPFL	M. Popovic (EPFL), P. Gao (EPFL), D. Tomozei (EPFL), J. Le Boudec (EPFL)	*On the Necessity of Traffic Shaping for PMU Measurement Data Streams*	Conf Power and Energy Automation Conference	March 2013

CNIT	A. Lombardo (CNIT), C. Panarello (CNIT), G. Schembra (CNIT)	*EE-ARQ: a Green ARQ-Based Algorithm for the Transmission of Video Streams on Noise Wireless Channels*	Journal Network Protocols and Algorithms, Vol. 5, No. 1	March 2013
EPFL	R. Khalili (EPFL), N. Gast (EPFL), M. Popovic (EPFL), J. Le Boudec (EPFL)	*Opportunistic Linked-Increases Congestion Control Algorithm for MPTCP*	Conf INTERNET-DRAFT, MPTCP working group	Febr 2013
TID	J. Montalvo (TID), J. Torrijos (TID), R. Canto (TID), I. Berberana (TID)	*Energy Efficiency and Cost Optimization of OTDR Supervision Systems for Monitoring Optical Fiber Infrastructures*	Conf International Conference on Networks (ICN 2013), pp. 75-80	Jan 2013
UTH, IHU, UOWM	S. Kokkinogenis (UOWM), G. Koutitas (UTH),	*Dynamic and static base station management schemes in cellular networks*	Conf IEEE GlobeComm	Dec 2012
EPFL	R. Khalili (EPFL), N. Gast (EPFL), M. Popovic (EPFL), U. Upadhyay (EPFL), J. Le Boudec (EPFL)	*MPTCP is not Pareto-Optimal: Performance Issues and a Possible Solution*	Conf ACM CoNEXT 2012	Dec 2012
CNIT	A. Lombardo (CNIT), C. Panarello (CNIT), G. Schembra (CNIT)	*An Adaptive Cross-Layer Approach for Energy-Efficient and QoS-Constrained Multimedia Transmission over Wireless Channels*	Conf The Second International Conference on Green Communications and Networking (GreeNets 2012)	Oct 2012
UTH	G. Koutitas (UTH),	*Control of Flexible Smart Devices in the Smart Grid*	Journal IEEE Transactions Smart Grids, Vol. 3, No. 3, pp. 1333 - 1343	Sept 2012
ICAR-CNR, Univ. Calabria	C. Comito (ICAR-CNR), D. Falcone (University of Calabria), D. Talia (ICAR-CNR), P. Trunfio (University of Calabria)	*A distributed allocation strategy for data mining tasks in mobile environments*	Conf Proc. of the 6th International Symposium on Intelligent Distributed Computing (IDC 2012),	Sept 2012

Polito	M. Ajmone Marsan (PoliTO), L. Chiaraviglio (PoliTO), D. Ciullo (PoliTO), M. Meo (PoliTO),	*Multiple Daily Base Station Switch-Offs in Cellular Networks*	Conf 4th International Conference on Communications and Electronics (ICCE 2012),	Aug 2012
CNIT, TUD	A. Zappone (CNIT), Z. Chong (TUD), F. Shen (TUD), E. Jorswieck (TUD), S. Buzzi (CNIT)	*Energy-aware competitive resource allocation in relay-assisted interference channels*	Conf Proc. of the 9th International Symposium on Wireless Communication Systems (ISWCS 2012),	Aug 2012
IMDEA, UC3M	K. Verma (IMDEA), G. Rizzo (IMDEA), A. Fernandez-Anta (IMDEA), R. Cuevas-Rumin (UC3M), A. Azcorra (UC3M)	*Greening the Internet: Energy-Optimal File Distribution*	Conf IEEE 11th International Symposium on Network Computing and Applications,	Aug 2012
CNIT, TUD	A. Zappone (CNIT), Z. Chong (TUD), E. Jorswieck (TUD), S. Buzzi (CNIT)	*Energy-Aware Non-Cooperative Resource Allocation in Relay-Assisted MIMO IC Considering Circuit Dissipated Power*	Conf Proc. of the Future Networks and Mobile Summit (FUNEMS 2012)	July 2012
UTH, AirCom, IHU	G. Koutitas (UTH), A. Karousos (Aircom), L. Tassiulas (UTH),	*Deployment strategies and energy efficiency of cellular networks*	Journal IEEE Transactions Wireless Communications, Vol. 11, No. 7, pp. 2552 - 2563	July 2012
EPFL	R. Khalili (EPFL), N. Gast (EPFL), M. Popovic (EPFL), J. Le Boudec (EPFL)	*Performance Issues with MPTCP*	Conf INTERNET-DRAFT, MPTCP working group	July 2012
PoliTO, Federal Univ. Juiz de Fora	A. P. Couto da Silva (Federal University of Juiz de Fora), M. Meo (PoliTO), M. Ajmone Marsan (PoliTO),	*Energy-Performance Trade-off in Dense WLANs: a Queuing Study*,	Journal Elsevier Computer Networks, Vol. 56, No. 10, pp. 2522–2537	June 2012
TUD, CNIT	A. Zappone (TUD), Z. Chong (TUD), E. Jorswieck (TUD), S. Buzzi (CNIT)	*Energy-efficient non-cooperative power control in relay-assisted interference channels considering circuit dissipated power*	Conf Proc. IEEE ICC 2012 Workshop on Green Communications and Networking	June 2012

TUB, Fraunhofer	S. Wiethölter (TUB), M. Emmelmann (Fraunhofer FOKUS, Berlin), R. Andersson (TUB), A. Wolisz (TUB)	*Performance evaluation of selection schemes for offloading traffic to IEEE 802.11 hotspots*	Conf Proc. of IEEE ICC 2012 - Wireless Networks Symposium	June 2012
TUB, Fraunhofer	S. Wiethölter (TUB), M. Emmelmann (Fraunhofer FOKUS, Berlin), Y. Chen (TUB), A. Wolisz (TUB),	*On the analysis of WiFi communication and WiMAX network entry over single radios*	Conf Proc. of Workshop on Convergence among Heterogeneous Wireless Systems in Future Internet (ICC)	June 2012
iMINDS	W. Vereecken (iMinds), M. Deruyck (iMinds), D. Colle (iMinds), W. Joseph (iMinds), M. Pickavet (iMinds), L. Martens (iMinds), P. Demeester (iMinds)	*Evaluation of the Potential for Energy Saving in Macrocell and Femtocell Networks using a Heuristic Introducing Sleep Modes in Base Stations*,	Journal EURASIP Journal onWireless Communications and Networking, Vol. 2012, No. 170, 10	May 2012
CNIT, TUD	A. Zappone (CNIT), Z. Chong (TUD), E. Jorswieck (TUD), S. Buzzi (CNIT)	*Green resource allocation in relay-assisted multicarrier IC networks considering circuit dissipated power*	Conf Proc. of the 3rd International Conference on Future Energy Systems (e-Energy 2012)	May 2012
IHU, UTH	G. Koutitas (UTH), L. Tassiulas (UTH),	*A delay based optimization scheme for peak load reduction in the smart grid*,	Conf Future Energy Systems: Where Energy, Computing and Communication Meet (e-Energy),Third International Conference on	May 2012
CNIT, Univ. Parma, Univ. Pisa	S. Buzzi (CNIT), G. Colavolpe (University of Parma), D. Saturnino (Scuola Sant'Anna di Pisa), A. Zappone (CNIT)	*Potential Games for Energy-Efficient Power Control and Subcarrier Allocation in Uplink Multicell OFDMA Systems*	Journal IEEE Journal of Selected Topics in Signal Processing, Vol. 6, No. 2, pp. 89 - 103	April 2012
CNIT, TUD	A. Zappone (CNIT), E. Jorswieck (TUD)	*Resource Allocation in Amplify-and-Forward Relay-Assisted DS/CDMA Systems*	Journal IEEE Transactions on Wireless Communications, Vol. 11, No. 4, pp. 1271 - 1276	April 2012

PoliTO, TUD	G. Alfano (PoliTO), Z. Chong (TUD), E. Jorswieck (TUD)	*Energy-efficient Power Control for MIMO channels with partial and full CSI*	Conf WSA 2012, Dresden	March 2012
PoliTO, UTH	L. Chiaraviglio (PoliTO), D. Ciullo (PoliTO), G. Koutitas (UTH), M. Meo (PoliTO), L. Tassiulas (UTH)	*Energy-Efficient Planning and Management of Cellular Networks*	Conf 9th International Conference on Wireless On-demand Network Systems and Services (WONS)	Jan 2012
iMINDS, ALBLF	W. Vereecken (iMinds), I. Haratcherev (A-LBLF), M. Deruyck (iMinds), W. Joseph (iMinds), M. Pickavet (iMinds), L. Martens (iMinds), P. Demeester (iMinds)	*he Effect of Variable Wake Up Time on the Utilization of Sleep Modes in Femtocell Mobile Access Networks*	Conf Wireless On-demand Network Systems and Services (WONS), 2012 9th Annual Conference on	Jan 2012
ICAR-CNR, Univ. Calabria	C. Comito (ICAR-CNR), D. Talia (ICAR-CNR), P. Trunfio (University of Calabria)	*An Energy Aware Framework for Mobile Data Mining*,	Journal Energy Efficient Distributed Computing Systems, vol 23	Jan 2012
CNIT, PoliTO	A. Zappone (CNIT), G. Alfano (PoliTO), S. Buzzi (CNIT), M. Meo (PoliTO)	*Non-cooperative resource allocation in multi-cell OFDMA systems with multiple base station antennas*	Proc. of the 8th International Symposium on Wireless Communication Systems (ISWCS 2011),	Nov 2011
EPFL, TUD	T. T. Tesfay (EPFL), R. Khalili (EPFL), J. Y. Le Boudec (EPFL), F. Richter (TUD), A. J. Fehske (TUD)	*Energy Saving and Capacity Gain of Micro Sites in Regular LTE Networks: Downlink Traffic Layer Analysis*	Conf 6-th ACM Workshop on Performance Monitoring and Measurement of Heterogeneous Wireless and Wired Networks	Oct 2011
ALBLF, PoliTO	A. Conte (A-LBLF), A. Feki (A-LBLF), L. Chiaraviglio (PoliTO), D. Ciullo (PoliTO), M. Meo (PoliTO), M. Ajmone Marsan (PoliTO)	*Cell Wilting and Blossoming for Energy Efficiency*	Journal IEEE Wireless Communications Magazine, Vol. 18, No. 5, pp. 50-57	Oct 2011

CNIT, TUD	A. Zappone (CNIT), S. Buzzi (CNIT), E. Jorswieck (TUD)	*Green power control and receiver design in relay-assisted interference channel wireless networks: A game-theoretic approach*	Conf Proc. of the 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies (ISABEL 2011),	Oct 2011
IMDEA, PoliTO	B. Rengarajan (IMDEA), G. Rizzo (IMDEA), M. Ajmone Marsan (PoliTO),	*Bounds on QoS-Constrained Energy Savings in Cellular Access Networks with Sleep Modes*,	Conf The 23rd International Teletraffic Congress (ITC 2011)	Sept 2011
CNIT, PoliTO	A. Zappone (CNIT), G. Alfano (PoliTO), S. Buzzi (CNIT), M. Meo (PoliTO)	*Energy-Efficient Non-cooperative Resource Allocation in Multi-Cell OFDMA Systems with Multiple Base Station Antennas*	Conf Proceedings of the 2011 IEEE Online Green Communications Conference	Sept 2011
CNIT, PoliTO	A. Zappone (CNIT), G. Alfano (PoliTO), S. Buzzi (CNIT), M. Meo (PoliTO),	*Impact of Incomplete CSI on Energy Efficiency for Multi-cell OFDMA Wireless Uplink*	Conf Proc. of the 17th EUNICE 2011 Workshop on "Energy-Aware Communications"	Sept 2011
TID	L. M. Apio (TID), E. Mino (TID), L. Cucala (TID), O. Moreno (TID), I. Berberana (TID)	*Energy Efficiency and Performance in mobile networks deployments with femtocells*	Conf Personal indoor and Mobile Radio Communications (PIMRC) 2011	Sept 2011
UTH	I. Koutsopoulos (UTH), L. Tassiulas (UTH)	*Challenges Demand load control for the Smart Grid*	Journal IEEE Network Magazine	Sept 2011
TUB	S. Chiaravalloti (TUB), F. Idzikowski (TUB), L. Budzisz (TUB)	*Power consumption of WLAN network elements*	Tech. Report TKN Technical Reports Series, Vol. TKN-11-002	Aug 2011
PoliTO	M. Ajmone Marsan (PoliTO), L. Chiaraviglio (PoliTO), D. Ciullo (PoliTO), M. Meo (PoliTO)	*Switch-Off Transients in Cellular Access Networks with Sleep Modes*	Conf 4th IEEE ICC 2011 Workshop on Green Communications (GreenComm4)	June 2011

CNIT, PoliTO	A. Zappone (CNIT), G. Alfano (PoliTO), S. Buzzi (CNIT), M. Meo (PoliTO)	*Energy-efficient non-cooperative resource allocation in multicell OFDMA systems with multiple base station antennas and MRC combining*	Conf Annual Meeting of the Italian Telecommunication Group	June 2011
EPFL, Univ. Belgrade, Univ. Prague	K. Dufkova (Czech Technical University in Prague), M. Popovic (EPFL), R. Khalili (EPFL), J. Y. Le Boudec (EPFL), M. Bjelica (Faculty of Electrical Engineering, University of Belgrade), L. Kencl (Czech Technical University in Prague)	*Energy Consumption Comparison Between Macro-Micro and Public Femto Deployment in a Plausible LTE Network*	Conf e-Energy 2011: 2nd International Conference on Energy-Efficient Computing and Networking	June 2011
PoliTO	M. Ajmone Marsan (PoliTO), M. Meo (PoliTO)	*Green Wireless Networking: Three Questions*	Conf 10th IEEE IFIP Annual Mediterranean Ad Hoc Networking Workshop	June 2011
PoliTO, IMDEA	M. Ajmone Marsan (PoliTO), A. Fernández Anta (IMDEA NETWORKS), V. Mancuso (IMDEA NETWORKS), B. Rengarajan (IMDEA NETWORKS), P. Reviriego Vasallo (University Antonio de Nebrija), G. Rizzo (IMDEA NETWORKS)	*A Simple Analytical Model for Energy Efficient Ethernet*	Journal IEEE Communication letters, No. 99, pp. 1-3,	June 2011
CNIT	S. Buzzi (CNIT), G. Colavolpe (University of Parma), D. Saturnino (Scuola Superiore Sant'Anna di Pisa), A. Zappone (CNIT)	*Potential Games for Power Control and Subcarrier Allocation in Uplink Multicell OFDMA Systems*	Conf 2nd International ICST Conference on Game Theory for Networks	April 2011

PoliTO,	G. Alfano (PoliTO), M. Garetto (Università di Torino), E. Leonardi (PoliTO),	*New Insights into the Stochastic Geometry Analysis of Dense CSMA Networks*,	Conf IEEE INFOCOM 2011	April 2011
FT	F. Saliou (Orange), P. Chanclou (Orange), N. Genay (Orange), F. Laurent (Orange), F. Bourgart (Orange), B. Charbonnier (Orange)	*Energy efficiency scenarios for long reach PON Central Offices*	Conf OFC/NFOEC 2011, Los Angeles, CA	Mar 2011
CNIT	S. Buzzi (CNIT), D. Saturnino (University of Cassino),	*A Game-Theoretic Approach to Energy-Efficient Power Control and Receiver Design in Cognitive CDMA Wireless Networks*	Journal IEEE Journal of Selected Topics in Signal Processing, Vol. 5, No. 1, pp. 137 - 150	Febr 2011
PoliTO	M. Ajmone Marsan (PoliTO), M. Meo (PoliTO)	*Energy efficient wireless Internet access with cooperative cellular networks*	Journal Computer Networks Journal, Special Issue: Wireless for the Future Internet, Vol. 55, No. 2	Febr 2011
ALBLF	C. S. Chen (A-LBLF)	*An Energy-Aware Protocol for Self-Organizing Heterogeneous LTE Systems*	Journal IEEE Journal on Selected Areas in Communications (JSAC)	
UTH	I. Koutsopoulos (UTH), L. Tassiulas (UTH)	*Control and Optimization meet the Smart Power Grid: Scheduling of power demands for optimal energy management*	Conf Proceedings of 2nd International Conference on Energy-Efficient Computing and Networking (E-Energy)	2011
CNIT	A. Lombardo (CNIT), D. Reforgiato (CNIT), V. Riccobene (CNIT), G. Schembra (CNIT)	*Design of a Temperature-Constrained Governor to Save Energy in an Open Multi-Frequency Green Router*	Jounral IJBDCN (Special Issue on Green Networking and Computing)	2013
TUD, PoliTO, CNIT	A. Zappone (TUD), G. Alfano (PoliTO), S. Buzzi (CNIT), M. Meo (PoliTO)	*Distributed energy-aware resource allocation in multi-antenna multi-carrier interference networks with statistical CSI*,	Journal EURASIP Journal on Wireless Communications and Networking	2013

TID, HWDU	J. Montalvo (TID), J. Torrijos (TID), J. Xia (HWDU), Y. Ye (HWDU)	*Energy Efficiency in PON Home Network Scenarios With Network Enhanced Residential Gateways*	Conf IEEE Conference of Networking, Sensing and Control	
iMINDS, TID, Bell Labs	S. Lambert (iMinds), B. Lannoo (iMinds), D. Colle (iMinds), M. Pickavet (iMinds), J. Montalvo (TID), J. Torrijos (TID), P. Vetter (Bell Labs USA)	*Energy efficient high speed triple play services in a major city PON deployment*,	Journal Journal of Selected Areas in Communications (JSAC),	
UTH	L. Gkatzikis (UTH), G. Paschos (UTH), I. Koutsopoulos (UTH)	*Medium Access Games: The Impact of Energy Constraints*	Conf NETGCOOP	2011
EPFL	R. Khalili (EPFL), N. Gast (EPFL), M. Popovic (EPFL), J. Le Boudec (EPFL),	*MPTCP Is Not Pareto-Optimal: Performance Issues and a Possible Solution*	Journal IEEE/ACM TRANSACTIONS ON NETWORKING	2013
ALBLF	I. Haratcherev (A-LBLF), A. Conte (A-LBLF)	*Practical energy-saving in 3G femtocells*	Conf IEEE ICC'13 - Workshop on Green Broadband access	
IHU, UTH	G. Koutitas (IHU), L. Tassiulas (UTH)	*Smart Grid Technologies for Future Radio and Data Centre Networks*	Journal IEEE Communications Magazine,in press	Exp. 2014
UTH, PoliTO, INRIA, CNIT	G. Koutitas (UTH), L. Chiaraviglio (Univ. Rome), D. Ciullo (INRIA), M. Meo (PoliTO), and L. Tassiulas (UTH)	Energy Aware Base Stations: the Effect of Planning, Management and Femto Layers	Journal Int. Journal of Electrical Engineering, Hindawi (accepted minor revision)	Exp 2014
TUB, IMDEA, PoliTO, iMINDS, ALBLF, UTH	L. Budzisz (TUB), Ganji Fatemeh, G. Rizzo, B. Lanoo, Mario Pickavet, Y. Zhang (PoliTO), M. Meo (PoliTO), A. Conte (A-LBLF), I. Haratcherev (A-LBLF), G. Koutitas (UTH), L. Tassiulas (UTH), M. A. Marsan (PoliTO), S. Lambert (iMinds)	'Dynamic Resource Provisioning for Energy Efficiency in Wireless Access Networks: a Survey and an Outlook	Journal IEEE Communications Surveys and Tutorials (Major revision)	Exp 2014

TUB, IMDEA, PoliTO, iMINDS, UTH, IHU	G. Koutitas (UTH), G. Iossifidis (UTH), B. Lanoo (iMINDS), M. Tahon (iMINDS), S. Verbrugge (iMINDS), P. Ziridis (IHU), L. Budzisz (TUB), M. Meo (PoliTO), M. Marsan (PoliTO), L. Tassiulas (UTH)	A Game Theoretic Approach for Mobile Network Operators Cooperation	Journal To be submitted January 2014	Exp 2014

Collaboration graphs, amount of joint papers and nb of partners per joint papers

5.2 Mobility actions

Involved partners	**Person**	**Topic**	**Period**
UTH-EPFL	Iordanis Koutsopoulos	*User association to base stations and femtocell fairness issues*	from 15/12/2010 to 16/12/2010
PoliTO-ALBLF	Delia Ciullo	*Sleep modes adoption for base stations in cellular access networks*	from 28/02/2011 to 28/02/2011
PoliTO-CNIT	Alessio Zappone	*Energy-efficient resource allocation in multiuser multicell MIMO networks*	from 07/03/2011 to 12/03/2011
PoliTO-CNIT	Giusi Alfano	*Energy-efficient resource allocation in multiuser multicell MIMO networks*	from 11/04/2011 to 15/04/2011
UTH-PoliTO	George Koutitas	*Energy Management of Base Stations in Deterministic Cellular Networks*	from 06/06/2011 to 10/06/2011
PoliTO-CNIT	Giusi Alfano	*Energy-efficient resource allocation in multiuser multicell MIMO networks*	from 28/06/2011 to 01/07/2011
CNIT-TUD	Alessio Zappone	*Energy Efficient Resource Allocation in Relay-Assisted Wireless Networks*	from 30/09/2011 to 12/11/2011
PoliTO-ALBLF	Giusi Alfano	*Energy-efficient rate-maximization in single and multi-user MIMO channels in absence of CSI*	from 17/10/2011 to 17/10/2011
PoliTO-TUD	Giusi Alfano	*Energy-efficient power allocation in MIMO networks under different fading scenarios*	from 20/12/2011 to 23/12/2011

CNIT-TUD	Alessio Zappone,	*Energy efficient resource allocation for the relay-assisted interference channel*	from 11/04/2012 to 06/05/2012
INRIA-PoliTO	Delia Ciullo	*Energy-efficient cellular networks: the effect of planning, management and femto layers*	from 23/07/2012 to 27/07/2012
INRIA-EPFL	Delia Ciullo	*Energy optimization in sustainable wireless networks*	from 05/11/2012 to 09/11/2012
INRIA-CNIT	Luca Chiaraviglio	*Energy Efficiency Across the Network Layers*	from 14/11/2012 to 16/11/2012
IMDEA-PoliTO	Balaji Rengarajan	*Quantifying and optimizing energy consumption in wireless access networks*	from 24/11/2012 to 29/11/2012
IMDEA-PoliTO	Gianluca Rizzo	*Quantifying and optimizing energy consumption in wireless access networks*	from 24/11/2012 to 29/11/2012
iMINDS-TID	Sofie Lambert	*Energy efficiency in NGPON deployments*	from 08/01/2013 to 18/01/2013
TUB-PoliTO	Fatemeh Ganji	*Collection of WLAN traces in dense WLAN to verify on/off strategies proposed in WP2*	from 21/05/2013 to 31/05/2013
TUB-PoliTO	Fatemeh Ganji	*Extraction of usage and mobility patterns of campus WLAN users*	from 30/06/2013 to 12/07/2013
ALBLF-PoliTO	Alberto Conte	*Green BS - Architectures and solutions*	from 02/07/2013 to 04/07/2013
UTH-CNIT	George Koutitas	*Dynamic Energy Management of Radio Networks*	from 24/09/2013 to 29/09/2013
PoliTO-TUD	Giusi Alfano	*Energy efficiency in presence of phase noise*	from 01/10/2013 to 07/10/2013

6. Conclusions

6.1 Global view

During the 3 years of activity of WP2, 77 papers were published in international Journals or conferences, and 21 mobility actions were organized between the WP2 partners. The general statistics for the published papers are

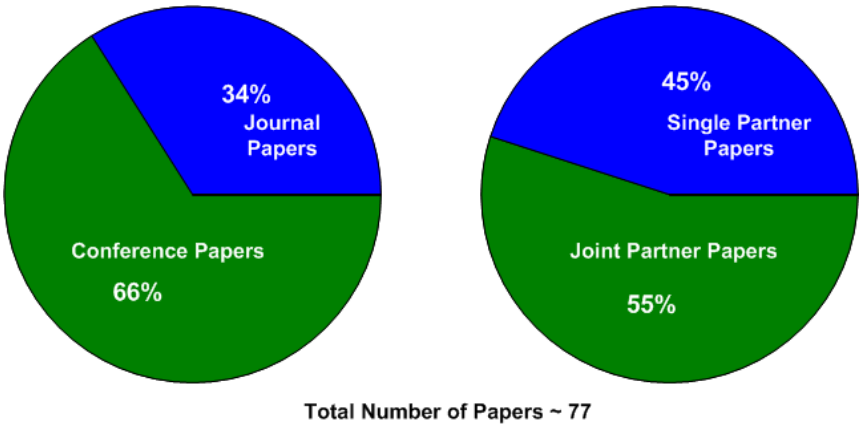

Figure 6. Statistics of WP2 TREND papers

6.2 Project integration (factual results in terms of collaboration)

This section describes the integration of WP2 TREND partners. It presents the mobility actions that were performed during TREND, in order to achieve the joint publications and results of WP2. The graph presented below does not include collaborations over teleconference meetings, but includes only mobility actions in the form of real travels.

Integration Graph for Mobility Actions

The total number of mobility actions was 21.

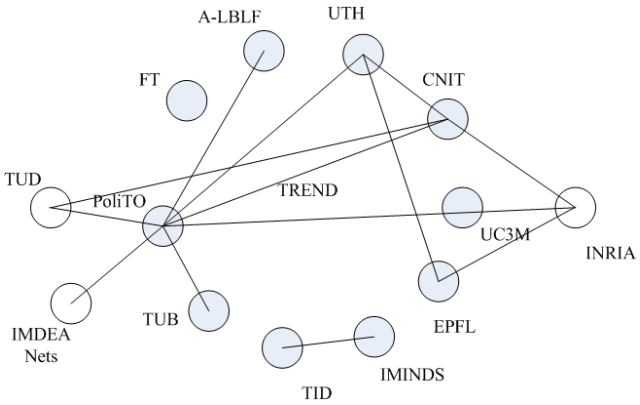

Figure 7. Mobility actions of WP2 TREND. 21 mobility actions. Non colored circles indicate collaborating institutions.

Integration Graph for Joint Papers

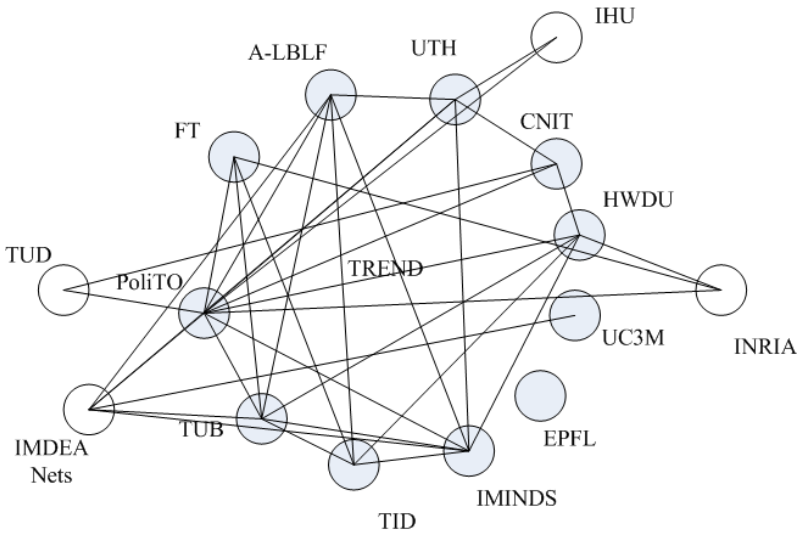

Figure 8. Joint Papers cooperation of WP2 TREND. Non colored circles indicate collaborating institutions.

7. References

List of all papers from WP2

[1] I. Haratcherev, A. Conte, “Practical energy efficiency in 3G femtocells”- International Conference INFOCOM, 2013

[2] Patent Application P201130693

[3] Iordanis Koutsopoulos and Leandros Tassiulas, ‘Challenges in demand load control for the smart grid’, IEEE Networks, vol. 15, no. 5, 2011

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8. List of Acronyms

ADSL	Asymmetrical Digital Subscriber Line
AP	Access Point
ARQ	Automatic Repeat Request
BS	Base Station
DSM	Demand Side Management
DR	Demand Response
FTTH	Fiber To The Home
GA	Genetic Algorithm
HAN	Home Area Network
ICT	Information and communication technologies
IP	Internet Protocol
IRA	Integrated Research Action
ISP	Internet Service Provider
MTCP	Multipath TCP
NGPON	Next Generation Passive Optical Network
OFDM	Orthogonal Frequency Division Multiplexing
OPEX	Operational Expenditure
RES	Renewable Energy Sources
SLA	Service Level Agreement
UHDTV	Ultra High Definition Digital Television
TD	Technical Domain
QoS	Quality of Service
WP	Work Package