

## Towards Real Energy-efficient Network Design

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THEME [ICT-2009.1.1]  
[The Network of the Future]



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# TREND rationale and motivations



- ❑ Energy-efficient networking has recently become a quite fashionable topic
- ❑ Too many buzzwords and too few data
- ❑ Need to understand which are the real possible gains, if any, of power awareness and power efficiency in networking

*The aim of TREND is to establish the **integration** of the EU research community in green networking with a **long term** perspective to consolidate the European leadership in the field*

# Power consumption of ICT



- ❑ ICT is today responsible for 2% to 10% of the worldwide power consumption
- ❑ In Italy, Telecom Italia is the second largest user of electricity (after the national railway system)
- ❑ Several studies predict that 50% of the world electricity will be used by ICT in a few years
- ❑ The new generations of Internet applications may require amounts of electricity that cannot be generated nor transported to major metropolitan areas
- ❑ This may end up limiting the penetration of broadband networking

# Why a NoE?



- The European technical community can claim both a strong background in networking and a high level of environmental consciousness
- There exists a significant market potential for green networking equipment
- In the above framework, a NoE is the perfect instrument for promoting awareness and contributing to build a sound knowledge base in the scientific community
- We chose a small NoE, with strong industrial participation and commitment, and a significant commitment on (joint) research activities

# Questions addressed by TREND



- *What is the real power consumption of ICT?*
- *In which sections of network infrastructures (home, access, core, data center) can energy-conscious approaches be more effective?*
- *Can optical technologies help in significantly reducing power consumption?*
- *Is the current Internet architecture, and TCP/IP in particular, energy friendly?*
- *What are the best suited engineering criteria and principles to actively support energy efficiency along the sequence of network design, planning, and operation?*
- *What kind of mutually beneficial incentives can be proposed to network operators, service providers, and users, in order to maximize energy efficiency?*

# TREND topics



## Energy efficiency in network infrastructures:

- ❑ Estimation of power consumption in ICT and collection of data
- ❑ Assessment of the fundamental energy-saving potential of network technologies and protocols
- ❑ Guidelines for policies and incentives to stimulate energy-efficiency in networks
- ❑ Redesign the home equipment for energy efficient communications
- ❑ Organizing the flying bits: saving energy on wireless access
- ❑ Power on/off strategies for energy saving and transparent connectivity
- ❑ Energy-efficient networking equipment
- ❑ Energy-efficient network design and control
- ❑ Energy-efficient service provisioning and content distribution
- ❑ Energy-efficient protection schemes
- ❑ Tools for power management and power management protocols

# TREND focus



- Contribution to both “retrofit” of existing networks and “clean slate” design of new networks
- Scope limited to networking; e.g., no direct attention to the estimation of the carbon footprint of the full lifetime of an electronic device, nor to power-related tradeoffs due to ICT technologies (e.g., the energy cost of telecommuting vs. the energy cost of physical commuting)

# TREND organization



- 12 partners (2 manufacturers – 3 telecom operators – 7 university groups) + 7 Collaborating Institutions (participating to research and integration activities with no budget allocation), all with significant previous experience in the technical topics
- duration: 3 years
- estimated effort: 446 person-months
- project budget: 4.4 MEuro (34% for research, 35% for integration and structuring, 21% for spreading of excellence, 8% for project management)
- EC contribution: 3.0 MEuro

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# TREND partners



- Network operators with experience on network design, planning, and management
- Equipment manufacturers with competence on the design of systems and of key networking elements
- Academic and industrial research groups with previous experience in energy-efficient networking, from component architectures, to protocols and algorithms, to network architecture, to design and management algorithms

# TREND partners



- (1) POLITECNICO DI TORINO
- (2) ALCATEL - LUCENT BELL LABS FRANCE
- (3) HUAWEI TECHNOLOGIES DUESSELDORF GmbH
- (4) TELEFONICA INVESTIGACION Y DESARROLLO SA
- (5) FRANCE TELECOM SA
- (6) FASTWEB SPA
- (7) UNIVERSIDAD CARLOS III DE MADRID
- (8) INTERDISCIPLINARY INSTITUTE FOR BROADBAND TECHNOLOGY
- (9) TECHNISCHE UNIVERSITAT BERLIN
- (10) ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE
- (11) CONSORZIO NAZIONALE INTERUNIVERSITARIO PER LE TELECOMUNICAZIONI
- (12) PANEPISTIMIO THESSALIAS (UNIVERSITY OF THESSALY)

# TREND actions



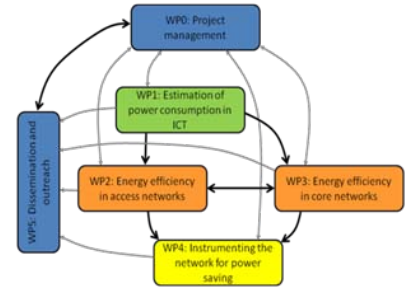
- Coordination and creation of an **identity for the European research** on energy-efficient networking through integration and collaboration amongst the different research groups involved in the Network of Excellence
- Definition of specific technical objectives to be jointly pursued within the Network of Excellence. Specific **Integrated Research Actions** (IRAs), and **Joint Experimental Activities** (JEAs) implemented internally to the NoE, will be open to external collaborations, and will play an important jump-start role in fostering integration and building synergies over complementary technical backgrounds and viewpoints

# TREND actions



- Establishing **contacts and links** primarily among FP7 projects, but also with national programmes and with projects outside the FP7-framework to exchange information and expertise, and to jointly work towards the definition of approaches that can be most effective in reducing the energy used by telecom infrastructures
- Organization of **workshops** targeting the dissemination of the TREND know-how and view on green networking to non-R&D participants, i.e. industrial representatives & policy makers. These workshops will make visible both the available expertise and the support that TREND is offering, as well as the results obtained on hot issues

# TREND organization



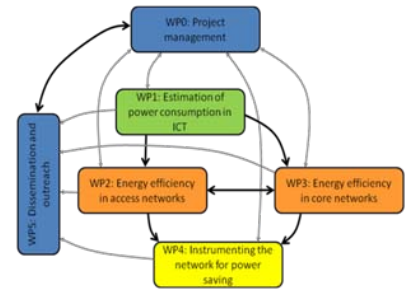
## ■ 6 workpackages:

- WP1: Assessment of power consumption in ICT
- WP2: Energy efficiency in access and home networks
- WP3: Energy efficiency in core networks
- WP4: Instrumenting the network for power saving
- WP5: Dissemination and outreach
- WP6: Project organization and management

## ■ Integration enablers:

- Integrated Research Actions and Joint Experimental Activities
- mobility and joint publications
- joint education and dissemination

# TREND organization



For WP1, WP2, WP3, and WP4:

- The scope of the WP is structured in **Technical Domains** (TD)
- Integrated Research Actions (**IRAs**) and Joint Experimental Activities (**JEAs**) were identified, with a strong partners' commitment
- **Deliverables** are planned to
  - present results of IRAs and JEAs
  - report partners' activities within the TDs
  - report dissemination and spreading of excellence actions specific for the WP

# WP1: Assessment of power consumption in ICT

■ Leader: Mario Pickavet, IBBT

■ Objectives:

- Assessment and estimation of network energy consumption
- Identification of major causes for network energy consumption
- Identification of key impacting factors to energy consumption
- Assessment and potential of photonic technologies and low-power electronics
- Consideration of energy-efficient strategies at the physical layer of wireless networks
- Analysis of the packet-switching versus circuit-switching paradigm
- Proposing guidelines for policies and economical incentives to promote energy-efficient behavior



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# WP1: Assessment of power consumption in ICT

- Technical domains:
  - TD1.1: Estimation of power consumption in ICT and collection of data
  - TD1.2: Assessment of the energy-saving potential of network technologies and protocols
  - TD1.3: Guidelines for policies and incentives to stimulate energy-efficiency in networks
- Proposed IRAs:
  - IRA1.1: Collection of data about energy consumption in network elements and subsystems
  - IRA1.2: Comparison of circuit versus packet switching paradigm in terms of energy efficiency

# WP2: Energy efficiency in access and home networks



- Leader: Leandros Tassiulas, UTH
- Objectives:
  - Identifying solutions for energy reduction, e.g. variable speed modes for interfaces and devices; network elements functionality allocation and the related architectures and necessary protocols
  - Enhance the current home equipment by adding energy saving features
  - Develop algorithms and protocols for efficiently turning on and off network devices (or parts of them) such as routers, set-top-boxes, access points, base stations, mobile handhelds and computers
  - Preserve user experience of being always connected, by applying profiling techniques, traffic shaping and forecasting, load balancing with suitable routing etc.
  - Propose novel green counterparts of traditional access techniques; green handovers, energy efficient cognitive radios, smart proxies, green p2p, energy-based contention
  - Optimize the energy performance of multihop wireless access networks by means of global optimization techniques and energy efficient routing protocols and power control algorithms

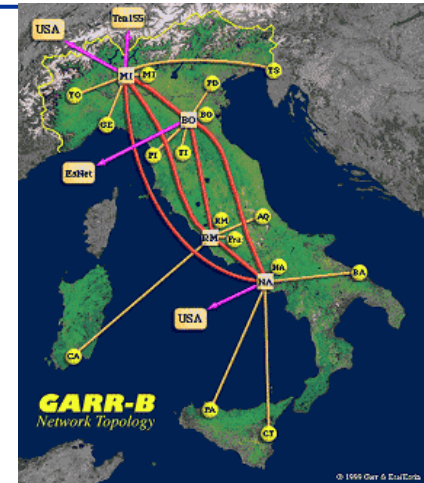
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# WP2: Energy efficiency in access and home networks

- Technical domains:
  - TD2.1: Redesign the home equipment (device consolidation and power state control) for energy efficient communications
  - TD2.2: Wired network access architecture and management
  - TD2.3: Saving energy on wireless access (“Organize the flying bits”)
  - TD2.4: Green protocols for handling wireless access from the network view (e.g., switch on-off access points or UMTS node-B’s)
  - TD2.5: Wireless multihop access
- Proposed IRAs:
  - IRA2.1: Low energy solutions directly applicable to Customer Premises Equipment
  - IRA2.2: On/off strategies for energy saving and transparent connectivity in WLAN access points and cellular femtocells

# WP3: Energy efficiency in core networks

- Leader: Esther Le Rouzic, FT
- Objectives:
  - energy-efficient network design, management and services
  - identify effective guidelines for the design core and metro networks
  - explore new technologies that could give a disruptive advantage in terms of energy efficiency
- Three axes:
  - node architecture
  - network design and management
  - service management

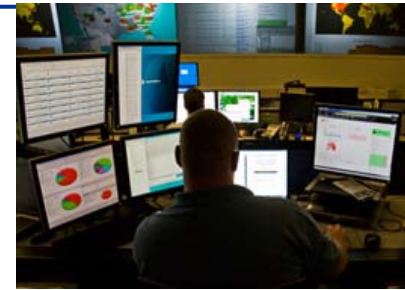


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# WP3: Energy efficiency in core networks

- Technical domains:
  - TD3.1: Energy-efficient core devices
  - TD3.2: Energy-efficient design of core networks
  - TD3.3: Energy-efficient service provisioning and content distribution
- Proposed IRAs:
  - IRA3.1: Energy-efficient use of network core resources
  - IRA3.2: Energy-efficient protection schemes

# WP4: Instrumenting the network for power saving



- Leader: Ivaylo Haratcherev, ALBLF
- Objectives:
  - **Network-wide energy measurement and management:** Extend existing network management systems to measure and report on energy consumption of network elements and the overall network
  - **Platforms, testing and validation:** Build experimental platforms and testbeds. Conduct simulations and tests on the new and on already existing platforms on energy-efficient approaches
  - **Field trials:** Introduce power-saving policies in user communities and evaluate the impact of those policies in the field

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# WP4: Instrumenting the network for power saving

- Technical domains:
  - TD4.1: Network-wide measurement and management
  - TD4.2: Platforms, testing and validation
  - TD4.3: Field trials
- Proposed JEA:
  - JEA4.1: Development of a tool for monitoring and controlling the power consumption of networking infrastructures

# WP5: Dissemination and outreach

- Leader: Carmen Guerrero, UC3M
- Objectives:
  - *Dissemination* of the scientific and technical results of other WPs: scientific publications at top conferences and journals, promotion and organization of workshops, conferences, events with the industry and special issues in journals
  - *Technology transfer* to the industry by establishing synergies with the industrial and academic communities
  - *Standardization* activities by liaison and contribution in relevant bodies (IETF, ITU, 3GPP...)
  - *Training* activities to support and strengthen dissemination
  - *Coordination* with other research projects at EU level on concertation and cluster activities and global level



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# WP5: Dissemination and outreach

- Tasks:
  - T5.1: Organization of conferences
  - T5.2: Teaching and training
  - T5.3: Standardization activities
  - T5.4: External relations
  - T5.5: Editorial activities

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# Spreading excellence

- Organization of workshops and events in major international conferences
- TREND international open workshop at project end
- Industrial workshop organized by TREND industrial partners
- Interactions with national and non-European initiatives on green networking
- Teaching of related topics in regular courses, with preparation of public teaching material
- Organization of one PhD school
- Feature topics on major international journals



# WP6: Project organization and management



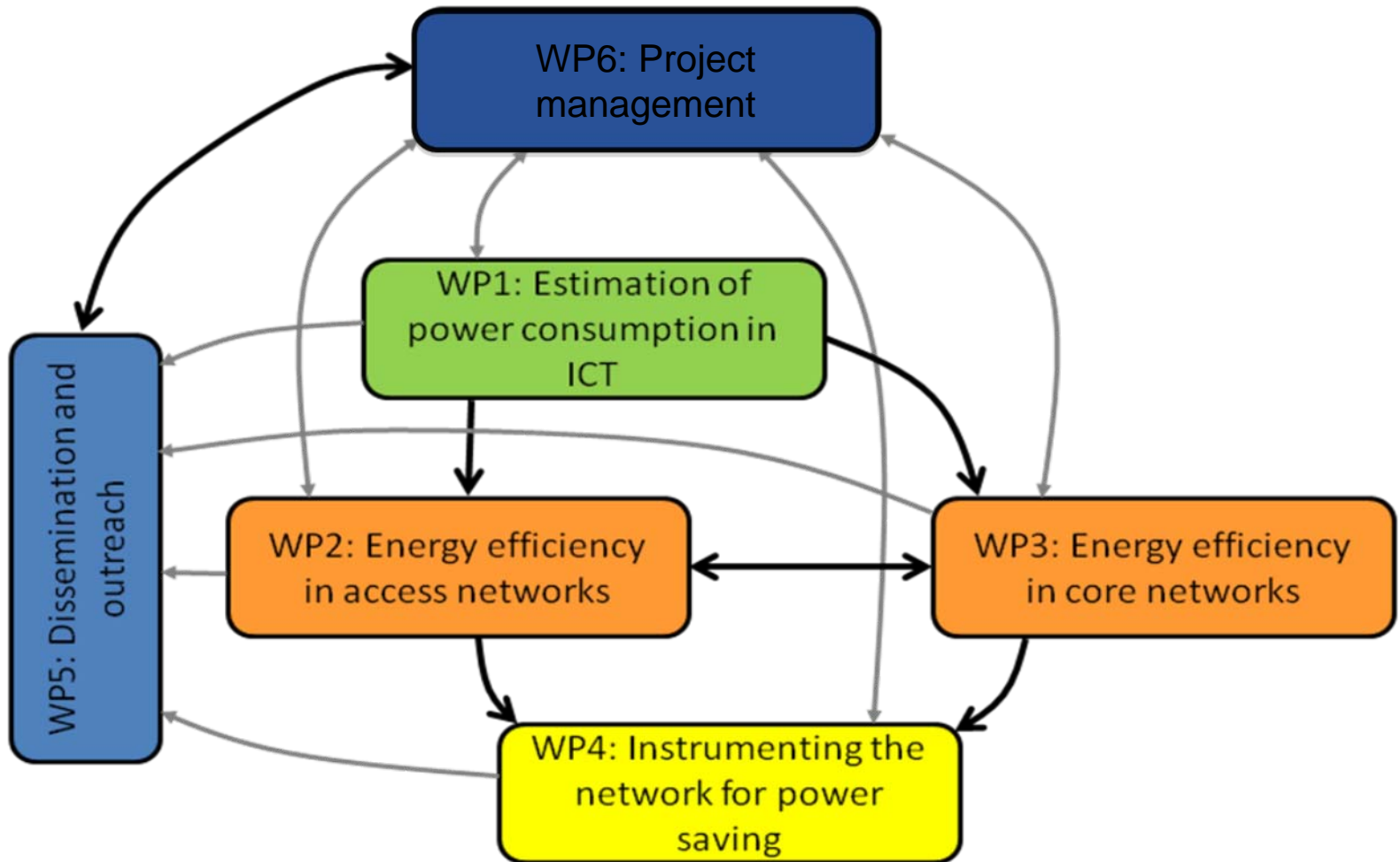
- Leader: Fabio Neri, PoliTO
- Objectives:
  - ensure that the overall objectives of the TREND, as outlined in the proposal, will be achieved within the foreseen time and budget
  - ensure an efficient decision process and a flexible and experienced coordination of the project activities
  - provide full and timely compliance with EU administrative and reporting requirements
  - prompt management of risks and unforeseen events

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# WP6: Project organization and management

- Tasks:
  - T6.1: Strategic project coordination
  - T6.2: Operational management
  - T6.3: Website and electronic project management tools
- The project website ([www.fp7-trend.eu](http://www.fp7-trend.eu)) will comprise a public part, providing general “live” information on the TREND project and its achievements, and a project-restricted part, which will act as an internal tool for information exchange and deliverable preparation, featuring:
  - directory and description of involved people
  - automatic generation of selective mailing lists
  - collection of administrative data
  - web-based support to periodic reporting
  - repository of deliverables, papers, and documents

# WP interplay



# Measurable integration



The success in the integration process can be quantitatively monitored by:

- Implementation and maintenance of the TREND website
- Number of joint papers and presentations
- Number of exchanges of personnel among involved partners
- Organization of dissemination activities towards industry, policy makers and the general public
- Contributions to the organization of major events in the field of energy-efficient networking
- Preparation of teaching material on green networking

# Durable integration



- Durability of integration depends on the level of integration within the lifetime of the project. It is important to proactively involve partners in the integration process (and the consortium has previous experience in managing a NoE): we expect significant collaborative work among partners
- The integration enabled by the NoE spawns multi-lateral partner collaborations, and easily leads to proposals for new research projects (among which EC IPs and STREPs, but also national research projects). International visibility and credibility of partners is increased, due to a NoE “branding” effect, hence opportunities for new collaborations are increased
- “The NoE was planned over a three-years time frame: a shorter duration (e.g., two years) would not permit integration to take place, while longer time frames may end up exhibiting a decline in partners’ commitment to integration”
- The commitment of TREND is to lay down the seeds of durable integration within the planned three-years duration of EC funding

# Strategic impact



- **Strengthened positioning of European industry** in the field of Future Internet technologies through the development of an energy-efficiency dimension in European products and services
- **Increased economic efficiency** of access/transport infrastructures through a significant reduction of the energy consumption
- Contribution to the development of European **standards for energy efficiency**, and generation of **European IPRs** in the new area of energy-efficient networking
- **Wider market opportunities**
- **Accelerated uptake of the next generation** of energy efficient **network** and service infrastructures



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More information at:

<http://www.fp7-trend.eu>

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