TEST DRIVING THE ENERGY EFFICIENCY OF A WIRELESS NETWORK

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HotMesh 2013
Getafe, June 4, 2013

SEVENTH FRAMEWORK PROGRAMME

OUTLINE

- TREND
- Key questions
- How to measure energy efficiency?
- TREND Test Scenarios
- An example
- Conclusions

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TREND: The FP7 Network of Excellence on Green Networking

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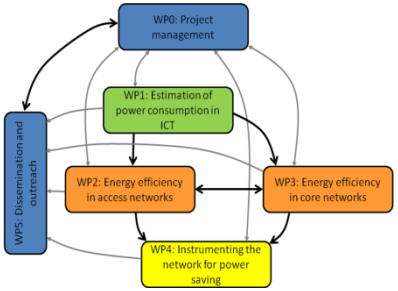
TREND rationale and motivations

*The aim of the TREND NoE 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*

TREND organization



- 6 workpackages:
  - WP1: Assessment of power consumption in ICT (IBBT)
  - WP2: Energy efficiency in access and home networks (UTH)
  - WP3: Energy efficiency in core networks (FT)
  - WP4: Instrumenting the network for power saving (A-LBLF)
  - WP5: Dissemination and outreach (UC3M)
  - WP6: Project organization and management (PoliTO)
- Integration enablers:
  - Integrated Research Actions and Joint Experimental Activities
  - mobility and joint publications
  - joint education and dissemination

TREND Consortium

Politecnico di Torino
Universidad Carlos III de Madrid
Interdisciplinary Institute for Broadband Technology
Technische Universitat Berlin
Ecole Polytechnique Federale de Lausanne
Consorzio Interuniversitario per le Telecomunicazioni
Panepistimio Thessalias

Academic

Alcatel- Lucent Bell Labs France
Huawei Technologies Duesseldorf GmbH

Manufacturers

Telefonica Investigacion Y Desarrollo SA
France Telecom SA
FASTWEB SPA

Operators

Current Collaborating Institutions

Current CIs

- Fondazione Ugo Bordoni, Italy
- Technische Universitat Dresden, Germany
- Deutsche Telekom Laboratories, Germany
- Institute IMDEA Networks, Spain
- ICAR-CNR (CNR Inst. for High Performance Computing and Networking), Italy
- International Hellenic University, Greece
- INRIA (Inst. National de Recherche en Informatique et en Automatique), France
- Boston University, USA

Pending CIs: plan of activities approved but agreement not signed

- Federal University of Juiz de Fora (Brazil)
- Zuse Institut Berlin, Germany (signature pending)

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Key questions

- How to measure energy efficiency?
- How to obtain meaningful and comparable metrics?
- How to measure existing networks?
- How to compare existing vs future networks?

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- **How to measure energy efficiency?**
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How to measure energy efficiency?

Obvious!

Measure power!

Power can be measured in several ways:

- Look at energy bill
- Use meters at different network elements
- Use power consumption models, and measure network parameters that appear in the model

How to measure energy efficiency?

Obvious!

Measure power!

But … not all power of a networking equipment is spent for networking purposes (losses, cooling, etc.)

- Measure **useful** power

$$\eta = \frac{P_{radiated}}{P_{input}}$$

How to measure energy efficiency?

Obvious!

Measure useful power!

But … if there is no network and we offer no service, we consume no power – and we want the service

- Measure ratio of **power over throughput** (Energy Consumption Rating - ECR)

$$\mathrm{ECR} = \frac{P}{T} \ [\mathrm{J/b}]$$

How to measure energy efficiency?

- … or measure ratio of **throughput over power** (Telecommunication Energy Efficiency Ratio - TEER)

$$\text{TEER} = \frac{T}{P} \text{ [b/J]}$$

How to measure energy efficiency?

Obvious!

Measure power/throughput!

But … if we cover a smaller area we need less power and we get more throughput – and we want service everywhere

- Measure ratio of **power over (throughput x area)**

$$\frac{P}{TA} \quad [\mathrm{J/bm^2}]$$

How to measure energy efficiency?

Obvious!

Measure power/(throughput x area)!

But … if we have more users we need more power because of interference and we get less throughput – and we all want service

- Measure (ITU) ratio of **power over (throughput x area x users)**

$$\frac{P}{TAN} \quad [\mathrm{J/bm^2}]$$

How to measure energy efficiency?

Obvious!

Measure power/(throughput x area x users)!

Actually, in rural areas the key issue is coverage (few users, low throughput)

- Measure (ETSI) ratio of **power over area**

$$\mathrm{KPI}_{\mathrm{rural}} = \frac{P}{A} \ [\mathrm{W/m^2}]$$

How to measure energy efficiency?

Obvious!

Measure power/(throughput x area x users)!

… and in dense urban areas the key issue is number of users

- Measure (ETSI) ratio of **power over users**

$$\mathrm{KPI}_{\mathrm{urban}} = \frac{P}{N} \ [\mathrm{W}]$$

How to measure energy efficiency?

Obvious!

Measure power/(throughput x area x users)!

But … if we have more bandwidth we need less power …
if we have faults we need protection equipment …
if we have renewable energy sources we can treat their power differently …

- So, **what should we measure?**

How to measure energy efficiency?

Not so obvious!

The problem comes from the fact that we want to compare different technologies (e.g, 3G vs 4G) in different scenarios (area, population, service, …)

But … we could define test scenarios to be used for all technologies, like car manufacturers do, to compare fuel consumption of different models

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TREND Test Scenarios

TTS(u,s) is the TREND Test Scenario in user environment **u,** subject to the service request pattern **s** with a given QoE constraint

The amount of brown energy used by the considered network in such scenario, expressed in Joules, is called ***TTS(u,s) brown energy consumption***

TREND Test Scenarios

User environment (examples – from EARTH)

- Dense urban, 3000 users per square km
- Urban, 1000 users per square km
- Suburban, 500 users per square km
- Rural, 100 users per square km
- Sparsely populated/wilderness, 25 users per square km

In urban areas, consider 1 square km, and 20% of active users. In other areas, consider 10 square km, and 10% of active users

Users are uniformly distributed over the service area.

TREND Test Scenarios

Service request pattern (examples)

- **Video:** each active user views a 5 minute video clip of size 30 MB which they download using TCP; for the QoE to be considered acceptable, the viewing must not be interrupted.

- **Download:** each active user downloads a file of size 1 MB using TCP; for the QoE to be considered acceptable, the download must last no more than 5 s.

TREND Test Scenarios

TTS(urban,video)

- service area of 1 square km
- 200 active users, uniformly distributed over the area
- each active user views a video of size 30 MB which lasts 5 minutes, using TCP; viewing is never interrupted

The amount of brown energy used by the network technology under consideration to provide this service to those users, expressed in Joules, is called ***TTS(urban,video) brown energy consumption***

Computing the energy consumption of a given technology requires a realistic **network planning** to determine the necessary equipment.

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An example

TTS(urban,video) energy consumption

- **3G HSPA** – 1900 MHz – 5 MHz channel – omnidirectional antenna – 500 m cell radius – 3 BS at 30% load – 1 kW each – 300 s – no RES – MTBF 1y

  TTS(urban,video) = 900 kJ

- **4G** - 2100 MHz – 5 MHz channel – 2x2 MIMO – omnidirectional antenna – 200 m cell radius – 12 BS at minimal load – 100 W each – 300 s – no RES – MTBF 1y

  TTS(urban,video) = 360 kJ

- **Disclaimer:** numbers above are not real

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Conclusions

Measuring the energy efficiency of a wireless network is not trivial

Comparing existing and future technologies is challenging

The definition of test scenarios can help, but requires a planning exercise, and a what-if analysis

Thank you

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Questions?

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