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Action IC0804

2 nd TRAINING SCHOOL BY COST 804 ACTION on "ENERGY EFFICIENCY IN LARGE SCALE DISTRIBUTED SYSTEMS"

Research Issues and Key Questions Identified during the Lectures and the Panel Sessions

Dates: 24 (09h), 25, 26, and 27 April (13h) 2012
Location: University of the Balearic Islands, Palma de Majorca, Balearic Islands, Spain
Local organizer: Assoc. Prof. Carlos JUIZ, Computer Science Dept.

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REMARKS: a) Some lectures contain research questions as identified by the lecturers; they are *not* included in this report.

b) The notes taken, and called "Questions and answers" are normally not split into questions and answers respectively, due to the long debates some did raise

A BACKGROUNDER on GREEN ITC

Prof L-F Pau, Copenhagen Business School (DK) and Rotterdam school of management (NL)

Abstract: This lecture covers the general contexts and frameworks in which Green ITC technologies are deployed: environmental regulations, emissions profiles from devices and activities, energy consumption and emissions evaluation methodologies, building regulations' impact as receptacles of ICT systems. It introduces cross-domain approaches and processes to reduce energy consumption and emissions from information, computing and telecommunications systems, as well as applications at design and usage levels. It is an introduction to the following domain specialized lectures.

First session of questions and answers (Day 1, April 24th):

- We are currently working to obtain more efficient technologies, in order to make them accessible to more people around the world. Despite that fact, what impact does this flow of technologies have on people and energy efficiency in particular? Do these new technologies only have localized temporary effects on the market, or do selected processes as well as a few technologies have a long term one on climate sustainability?
- In general the energy savings impact of specific technologies alone is minimal, and even more so for algorithms, as they assume fixed operating conditions which rarely happen due to changes in usage, behaviors and demand
- Let's suppose we have two products, with common functional and performance specification. As an engineer you put them in front of a customer; but consumer decides, and which one will he chose and why that choice? This is a common problem in economics and marketing research. Will you choose a more eco-friendly special product with lower energy footprint, or the cheaper mass produced product with no unique energy savings characteristics?
- Supporting and developing green products involves how to create incentives or differentiators so that they sell more if they exhibit energy efficiency?
- One should choose the place for a business deployment according to one's needs and the environment/context which one works with, in order to have an efficient and sustainable business. (example: data centers built in the northern hemisphere close to the polar circle)
- Should be implemented feedback from the services market (implicit to the consumers), so that service consumers favor globally greener products and services (e.g. Green tariffs in telecommunications and Internet)
- What are the contributors to the global energy costs? What about the costs of solar energy and renewable energies? Their prices are strongly influenced by the environment in which they are being implemented?
- Why don't we start using power concentrators (like solar towers)? Well, we know now that they are more expensive and delicate than other technologies…
- We should discuss about thermal power (geo-thermal) used in industry and supplied to population in urban areas.
- There are strong reasons why we need first to understand the existing technologies in order to come up with innovations and something new from the research and development (R&D) departments.

- There are organizations around the world which have as a main goal to implement and develop new industrial standards in order to improve the life we are living.
- Is it all right that utilities receive only a payment (in Euros), or should they get more numbers and data about the user systems and process' attributes (energy efficiency, usage levels, number of users by power outlet, etc.)? Also, users should know how green it is the energy they are using.

Key research questions:

1. Pick a technology and try to work on it to make it energy efficient (and not just performant on other measures) . This means technology will still be cheaper (by mass production) and greener in the long-term

- The more energy-efficient --> does mass production / distribution learning curve still apply?
- Performance versus energy savings and cost: what do you choose ?

2.Interest how energy savings impact user choices. If you show that you're greener, you should have more clients, but not always so ! . Attractiveness of a given product/service should be based on the energy-saving characteristics

3. Data center energy savings depends primarily not on technologies but on preferable locations (because of cooling); predict where data center should be built based on which technology by using explicitly the location-issue.. However, reality is that other factors affect this kind of decisions (subsidies, land, security).

4. Heterogeneity of data centers emissions due to very different energy usage mix (types of sources of energy).
5. Green and CO2 certificates (covered in the next lecture)
6. Solar energy: location dependent costs and the effects. Technological problems due to heat transfer. Problem of thermal management.
7. Lack of established recognized methodologies to define the net energy savings effects. Methods are highly domain dependent. Sometimes only feasible approaches are certification, as calculations are impossible. New units to define energy efficiency?

- Some organizations or fields have their own methodologies (standards, certificates, etc.)
- Different sectors have different approaches... might there exist something that puts together all sectors? It is essential to use systematically anyway the life-cycle approach (materials, production, operations,logistics, dismantling) (Case of optical fiber with huge difference between emissions in operations and in all other steps of lifecycle, making it much less green than wireless).

8. "450 Scenario". Given the government influence, it would be good to impose regulations,and make third party verified data public

Second session of questions and answers (Day 1, April 24th):

1. Reseach on graphene - not only for circuits, also for storage
2. Superconductors - the range is limited, the cost is high - very specific purpose. Pilot installations for high-voltage long-range transmissions (very expensive)

Third session of questions and answers (Day 2, April 25th):

- Automatic technologies to increase efficiency in the buildings. SMEs are innovating in this space. They are not always standard. Most electrical utilities don't like them.
- Make the DC power transmission easier (from far-apart places). Suppliers don't publicize the energy savings as much as they should: collect, validate and publicize. They don't have the evidence at this point in time.
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SMART GRIDS AND ENERGY EFFICIENT ICT

Prof. Paul Nicolae BORZA, Transylvania University (RO)
<u>Abstract</u>:
1-Definition of Smart Grids (SG)
2-About the fusion between energy and Information, and the role of grids' fusion in improving the energy efficiency in power generation and distribution.
3-How are implemented generation and control in power networks; technology components in the production and distribution of electrical energy; active versus reactive power; power generation -based components; secondary and tertiary reserves.
4-New changes to the power grids ("smart grids"):
5-Consequences of power grid modernization
6-How is the trade-off between dependable power versus the power grid evolution?

First session of assertions, questions and answers (Day 1, April 24th)

- The smart grid (SG) vision supposes to transpose into reality the trinomial vision about power networks unifying the three main entities involved: consumers, traders and energy providers, defining functionalities and inter correlate them.
- The main goal is to offer better solutions for energy supply in terms of power, availability, reliability, and minimal eco-foot print
- A central procedure that facilitates the SG implementation is AMI (Advance Metering Infrastructure); it reveals at any time the power flow distribution in the power network, ensures a bidirectional communication, and implements dynamic tariffs for "prosumers". It intends to illustrate in the energy market the real efforts made (material, operational economical and eco-footprints) to obtain electric power supply services
- SG represents a huge technological advance (hope!) But in the same time it is a challenging problem as a result of its complexity. In fact, the implementation of SG will generate a real "fusion" between energy & information with benefic effects for all society: consumers, provides and traders of electric energy.
- Research in electronics and technologies should improve and point to how to obtain better services and supply better products.

- What about the research done till this point? It still does not exploit the advantages of the new technologies, meaning that the new products still don't satisfy the market needs in terms of operational stability in power networks, and ease of implementation in large distributed systems.
- How could we reduce the loss of energy between production plants and the consumers?
- Do simulation studies show any significant difference between classical systems and a distributed, decentralized system? Simulations done so far, for smart grids, show no improvement over classical networks. Is it possible that the software used isn't per formant enough for simulating the systems we want to implement? Should better models and simulation software bring a glimpse of hope on the problem and be a starting point for future studies?
- "Smart" measurement", means that one should have all the information needed about the power grid. Is it hard to forecast the implication of introducing such a device in the grid? What happens when the device is in working condition or when it is off-line (islanded, or made fault tolerant)? How do these two states affect the power grid?
- In the future, are needed further studies about the technological stress of the components used in industry and in consumer devices.

Identification of key research questions:
Operational side:
1. To think about aspects related to the main functionality that smart grids will have in the future. Resident and reliable systems.
2. How to sync the load with the generation, especially in data centers. Very dependent on the technology of the computers (taking their heterogeneity into account). Need to minimize the full eco-footprint (carbon, waste, pollutant gas emissions different from CO and CO_2).
3. Why general-purpose operating systems do not fit in the consumer scenario. They do not satisfy the real-time constraints which power network stability require. Characteristics they should have in order to satisfy stability.
4. Loss reduction

Structural side:
5. How can you maximize the usage of the communication network inside the system in correlation to what is happening in power network.

Second session of assertions, questions and answers (Day 2, April 25th)
Structural side:
- Mobile storage of energy may become a reality if super capacitors are used.
- Yes, it is a reality but has a large complexity. In the future the devices will be able to fully control a bidirectional energy transfer as result of deep and large scale implementation of energetic devices endowed with information and communication elements (ICT). At the same time, the efficiency of batteries is poor compared to the life cycle of a specific product (ex. cars). By using super capacitors, this issue might be solved, but future investigations should be done in order to be able to bring some data on this topic.

- What about the time flexibility? Has anyone done research in this field, with those types of electrical components? Research has been done by state institutions like the University of Eindhoven, ENEA (Italian National agency for new technologies, Energy and sustainable economic development), and by private companies like Maxwell (US & Switzerland), BatScap (France), NESCAPP (Korea & US), and Russia.

- In term of life cycle, is the use of fuel cells is more efficient than other technologies? What studies have been done in this area?
- What are the main requirements to implement a new power plant? Is a solution using virtualization? Yes, in future concepts of Distributed Energy Resources (DES).

Key research issues:

- How we can make systems with a very high resilience.
- Cars are able to generate energy as well as to consume it, and to keep a balance. Could they auto-generate energy and keep it in batteries? The main problem is the lifetime of batteries. (with a solution though provided by Blue car 1 year batteries (France)). Some studies are related to fuel-cells for big vehicles, materials (platinum: costly), storage (stationary applications such as: big UPS systems, airport emergency power supply system implemented using fuel cells like in Munich. To start such systems you need super caps, and centralized supply stations (for specific users).
- BMW: hydrogen for their cars. They have converted an ICE car into a hydrogen base car using a modified ICE with hydrogen as fuel and adding a tank (H_2 reservoir well sealed).
- Virtual power plants: Several groups try to implement systems to try to solve the complexity. Such research projects exist both in EU-FP5, 6, 7 and US-California and DOE initiative. See also Prof Pau's lecture notes for examples of pilot deployments. It is about dividing the tasks in a central network. The EU project FENIX focusses on building the virtual power plant concept and component implementations (FENIX boxes).
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ALGORITHMIC TECHNIQUES FOR REDUCING ENERGY CONSUMPTION OF COMMERCIAL WEB SEARCH ENGINES

Dr Berkant Cambazoglu, Yahoo Research (Spain)
Abstract : Commercial web search engine companies make costly investments on very large compute infrastructures to be able to cope with the growth of the Web and user query traffic volumes. The massive compute infrastructures maintained by the search engines lead to high amounts of energy consumption and, in turn, high electricity bills. Reducing the energy consumption is crucial for the profitability of a search engine and this should be carefully done, without degrading the quality of the service provided by the search engine.

First session of questions and answers (Day 2, April 25th)

- Are the popular search engines implemented as a centralized system? Are P2P (peer-to-peer) search engines good enough for today's needs?

Most small- or medium-scale search systems are centralized. However, large-scale web search engines are in general distributed systems involving a number of data centers (typically four or five large centers). P2P search engines, which are composed of a much larger number of peers, also exist. These search engines are, however, far from meeting the efficiency and result quality requirements of users. Therefore, P2P does not seem to be the answer the web search problem in the near future.

- Why is web search different than the traditional search that we know from our algorithms course (e.g., binary search)?

Web search is more like a sorting problem in nature. Given a query, the problem is to sort a collection of documents based on their relevance to the query. That is, the objective is not to look for an item among a given collection of items because we do not know what item or items to look for before starting the search process.

- Do web crawlers rely on machine learning algorithms?

The web crawling process and in particular the prioritization of the URLs to be fetched is guided by relatively simple heuristics. Typical examples are breadth-first crawling or page-quality-based web crawling. Machine learning used as an additional step to filter the downloaded content or feature extraction (e.g., spam filtering or language/region identification).

- Is there a possibility to build crawlers that respond to semantics and topics found in plain text?

There are already such crawlers, known as focused web crawlers. These crawlers start from a set of seed pages and try to download web pages that are related to a certain topic earlier than the remaining pages, thus speeding up the rate of discovering related content.

- What are the important features used by the ranking systems of search engines?

The most important feature types are term features, query term proximity features, link analysis features, spam features, click features, and social media features.

- How can we reduce the energy consumption? Which search architecture we should implement?

There are many alternative optimizations. The most important optimizations for reducing the energy consumption are index compression, early termination of query processing, data caching, and index pruning. In terms of the indexing architectures, the alternatives are pruned index, tiering, and collection selection. The optimum choice depends on many external factors, e.g., the size of the index, the query rate, the hardware, and is not easy to identify a single architecture that works well in all cases.

- How could universities test and demonstrate the performance of different architecture, taking in account the fact that they don’t have access to data cluster as large as the one used by Google or Yahoo?

A potential option is to write a research proposal trying to get access to the data and compute resources of these companies, upon a call for proposals from these companies or based on scientific collaboration programs such as the Webscope program of Yahoo!.

- In order to reduce energy consumption, is the use of new storage technologies (SSD, flash) a viable option?

Currently, these technologies are expensive. In the future, they will definitely be viable.

- What is the energy footprint of a single query?

There are different numbers reported regarding this issue. But, so far, they do not go beyond being speculations.

Key research questions

- Usage of flash disks for storage to reduce the energy footprint.
- Energy savings by using less hardware.
- Assess the energy costs of memory - compression and uncompression of data structures - schemes that operate on compressed data in an energy-efficient way.
- Web 2.0 people expect that searching is more than searching text (search object) - people want real answers. How does that change the modeling of DC and the energy-consumption. Impact on search engines?
- Mobile search, changes lots of assumptions.

Second session of questions and answers (Day 2, April 25th)

- Do geographically distributed search systems bring energy efficiency?

Yes. The latency between the users and the data centers decreases. Therefore, the query response times go down. Also, the data centers become much smaller and the associated cooling costs go down.

- Study scenario: a query is send to data center A which passes it to data center B. Is data center B to send the answer directly to the client or it has to send the answer to the A data center?

In theory, the answer can be directly returned to the user by data center B. But, in practice, it is difficult to change the way TCP/IP protocol works. Therefore, the results will be returned by data center A.

- Does the extra traffic created by moving information between data centers brings an significant increase in energy consumption? Is it useful to have directly optical connection between the data centers instead of use the classical network?

The overhead on the network and the related energy consumption should not be significant, especially if it is compared to the cost of processing a query in a large search data center on thousands of computers.

- Is the cost of utilities an important decision choice when it comes to build data centers?

It is definitely so. Most data centers are tried to be build on cooler regions with low tax rates and easy access to energy.

Research questions

- Little work on distributed web crawling. Partition the web by language or country to minimize the work done by the crawler.
- Passive URL discovery. A system where the routers push the information to the crawler (instead of the crawler pulling it from the Web). URL discovery by external agents. The pages that are accessible to crawlers would be discovered.
- Financial perspective of caching. Give caching decisions based on the financial impact.
- Caching. The result caches located in the remote data centers can be used to server the queries.
- Green search engines. Reduce the carbon footprint of each search engine through web crawling (crawl websites that consume green energy) and query processing (shift workload to green data centers**).**
- Shift workloads between data centers. Reducing space of data centers, so that the cooling costs are reduced.
- Temporal energy price differences. Exploit the cooling systems that yield the best greening effect.
- The costs of transferring data to other data centers (costs of the networking equipment for transmitting the data). Queries travel through many routers.

ENERGY EFFICIENCY (EE) OVER WIRED NETWORKS

Assistant Professor Alberto E. García, Telematic Engineering Group, University of Cantabria (ES)

Abstract: *This tutorial exposes the actual state of the standards and gives new proposals to reduce the energetic consumption balance in fixed FGN network deployment. This reduction is focalized into two different ways: link and node based solutions. The first solutions use variations of actual transmission technologies to minimize the consumption of the physical links between transmissions, or to reduce the number of active paths. The second group of solutions tries to reduce the global bandwidth in the networks, localizing service control directly under the influence of the clients, and distributing the load of centralized datacenters towards smaller peripheral ones. Additionally, this lecture gives a view on the impact of the application of these techniques according to several scenarios, from the point of view of the backbone and access networks, and their effect on the design and deployment.*

1. *Actual state*
2. *Link based solution*
3. *Node based solutions*
4. *EE over the backbone*
5. *EE over the access*

First session of questions and answers (Day 3, April 26th)

- At the transport layer, should the protocols be aware of the network in order to use it efficiently (from the energy efficiency point of view)? Could be implemented a few solutions to reduce the overhead and unnecessary message exchange.
  As a general point, "energy aware protocols" might involve all the seven OSI layers:
  - At the applications layer we could include application, presentation and session OSI layers combined together, as TCP/IP considers; some solutions are directed towards cloud computing and virtualization.
  - From the point of view of the transport layer, some proposals consider variations to the TCP protocol
  - At the network layer, the tendencies point toward the simplification of the IP routing functionality, avoiding to open the IP header using the labeling over the link layer (e.g MPLS); in the future, one could decide the final path depending on the selected lambdas (optical switching when feasible !)

- It has been tried to implement energy efficient protocols, and to manage the energy consumption between the transport layer and application layer (energy used to convert information between different layers inside a network endpoint)?
  One of the conclusions could be that the most efficient solution might be one that would simplify the major part of the functionalities that TCP/IP actually includes. Integration of different networking functions inside the same protocol / device is one of the tendencies that cloud computing and data center optimization consider. Transport of the data must to be a simple media, without other considerations than the volume of transported data. What is the best application from the EE point of view? Video streaming, high volume of data over burst with deterministic durations.

- What happens over time with the quality of services (QoS)?
  Have been tried a few solutions to improve the QoS but they aren't necessary energy efficient because actually there is an inverse proportional relation between them. We should only make some compromises to assure a minimal QoS with enough EE results.

- What is a scenario for a future development? We know that industry and other market segments will need more bandwidth and increase of speed and reliability. We know also that the IP protocol and the networks aren't ready to deliver that. Maybe the use or implementation of scalable networks would improve something?
  Actual networks are reaching physical limits which cannot be assumed if their real energy consumption is not limited. Operators know that EE is not a solution but a near future obligation and they then have to consider a future where two possibilities appear:
  - To migrate existing networks, replacing existing devices by new devices with EE. This solution depends on the evolution of network devices and suitable adaptability of the existing topologies.
  - To develop new networks according to EE criteria. This is only a solution for new operators or integrators of both network worlds: mobile & wired.

Second session of questions and answers (Day 3, April 26th)

- ISP's should be concerned about user experience and efficient energy utilization?
  Providers could obtain benefits using the user behavior as a feedback for their user information. All the changes in the use of the network by the customer could determine the viability of different solutions accordingly to a determined EE policy.
- Is it possible in the future to suggest a migration route starting from the current technologies used in the market?
  Each provider/operator maintains his own policy about network deployment. However, technology determines inflection points into these policies, and the convergence of different deployments and solutions may result.

- There are many ways to implement new networks but, has energy usage been taken into account? Are we sure that we implement the best solution?
  EE is a relatively new concept (at least for network operators) and they are still recovering their investment into existing deployed networks. New deployments look for a quick market introduction without other considerations. Only future regulations could force a reconsideration of the existing networks but, and it is only an opinion, existing networks will be reconfigured following the new paradigm (EE) without deployments of new networks.

ENERGY CONSERVATION IN WIRELESS SENSOR NETWORKS

Prof. Giuseppe ANASTASI, Dept. of information engineering, University of Pisa (IT)

Abstract: *Wireless sensor networks (WSNs) consist of a number of sensor nodes deployed over a geographic area. Sensor nodes are tiny devices typically powered by batteries with a limited energy budget. Energy conservation is thus the main concern in the design of any WSN-based system. This tutorial will first analyze where and how energy is consumed at sensor nodes. Then, it will introduce a taxonomy of the main approaches to energy conservation in WSNs, and it will survey the main techniques used in practice.*

First session of questions and answers (Day 3, April 26th)

- Can we save energy by compressing/aggregating data? Can MAC protocols be a solution for this issue? What solution is the most suitable one for our working environment?

Data-driven approaches, including data compression and aggregation, are valid approaches for reducing the amount of data to manage and, hence, the energy consumption. However, typically, they are not enough. In general a combination of different approaches must be used for achieving significant energy efficiency.

- Should we try to reduce the amount of transmitted data, or should we try to develop energy-efficient MAC protocols?
  Both approaches must be considered in practice (it also depends on the specific application that we are implementing). Data-driven approaches typically reduce significantly the amount of data to be transmitted toward the sink. However, this does not necessarily result in a proportional energy saving, because other factors impact on the overall energy consumption (e.g., network maintenance). Anyway, a general approach to

energy saving for all applications cannot be established, because we have to take into account the specific needs and capabilities of each system being implemented. Also, we need to take a holistic approach to energy efficiency. It has been shown that reducing the energy consumption of a single system component might also result in an increase in the energy consumption of the overall system.

- What happened with standardization? Is it a viable option? If it is, why isn't implemented yet? Who should create a new standard in this domain?

Actually there are some standards already available, e.g., the IEEE 802.15.4/ZibBee standards that defines the networking architecture. Other standards are also available. However, please consider that WSNs fall in the field of embedded systems. In addition, energy conservation is a typical cross-layer issue, which also depends on the specific application. Hence, a general standard for energy conservation cannot be established.

- Why we don't harvest energy from the environment in order to power several systems that use sensors?

Energy harvesting from the external environment is definitely one of the option used to extend the lifetime of a WSN. However, even when harvesting energy from the external environment, energy must be used very efficiently. Hence, energy conservation is still required.

- Is a good research domain trying to implement array sensor for the medical industry? (wearable sensors, sensors for remote monitoring, etc.)

E-health is definitely one of the most promising application fields for WSNs.

Key-research questions (from lecture notes)):

- Data-driven approaches can significantly reduce the amount of data to be transmitted to the sink node (up to 99% and beyond). However, this does not necessarily result in a proportional energy consumption reduction.
- Topology-management can provide an energy consumption reduction depending on the degree of redundancy in the WSN. They trade lifetime for redundancy (however, some redundancy is always present).
- Power management eliminates idle times. Hence, it can provide large energy reductions with limited costs
    - The tradeoff between energy efficiency and robustness must also be considered when designing a power management scheme.
- General sleep/wakeup schemes or MAC-layer schemes?
- And which MAC protocol? TDMA, B-MAC, or IEEE 802.15.4 MAC?
- Is the radio the most consuming component in a sensor node?
    - In some practical application sensor have a power consumption similar or, even, larger than that of the radio
    - We typically compare power consumptions, but not energy consumptions should be considered

    - Since the acquisition time of a sensor is typically larger than the transmission time of a packet, a sensor may have an energy consumption much larger that that of the radio
- Power management vs. energy harvesting: are they really alternative approaches?
- Energy-aware protocols for WSNs using energy harvesting is a good research topic.

Key-research questions (after lecture):

- Data-driven approaches: where does the solution lie (compressing data vs sending fewer messages)? development of new protocols? Some applications have no good protocol to optimize. What is the best approach? → application-specific. WSNs must be application-specific, even though there are some general solutions
- What about standardization? Seems not to grow. Zigbee/BT standard (discussion about Zigbee/BT in cars replacing wires in car by wireless solutions + energy harvesting techniques)
- Wireless sensors could use energy harvesting techniques from the electromagnetic environment → most of the debate of minor improvements would be useless.
- Room for research in WSN: when you deploy a WSN in a real environment you find new problems → experimental set-ups are the source of new research problems.
- Problem of intrusive sensor networks (e.g., medical applications).
- Impact on environment. Future: lots of intelligent devices around us that communicate transparently with wearable devices (pervasive computing scenario). We cannot control this trend. The question is: can they increase the quality of our life?

Second session of questions and answers (Day 4, April 27th)

- WSNs for energy efficiency (e.g., in buildings, data centers, etc). Which is the best place where to use this kind of sensor networks in order to obtain valid data for research purposes?
- Are there studies in the literature to investigate more aspects regarding the examples you have given? (An example about adaptive lighting system in road tunnels.)
- WSN for adaptive lighting in road tunnels. What kind of light bulbs have been used in that practical application?
- Calibration of sensors. Very critical issue in practice, even if not considered in most of research papers. There are many situations where the mis-calibration lead to erroneous acquitions.

ENERGY and EMISSIONS SAVINGS IN PUBLIC WIRELESS NETWORKS

Prof. L-F Pau Copenhagen Business School (DK) and Rotterdam school of management (NL)

Abstract:

1. As public wireless networks constitute today the dominant communications facility globally, and as it is historically also the ICT system having first focused on energy systems, the tutorial will focus on key technologies, energy sources (incl. renewables) and trade-off/ selection methodologies. It will also show and quantify how end user service demands drive energy consumption alongside infrastructure, and how inefficient energy operations management affects the emissions and business outcomes.
2. Case demonstration: Will be demonstrated a simplified version of a unique industrial tool whereby mobile network operators design 3G/LTE wireless networks for best energy efficiency, and run these operations with minimal on-going energy consumption .It serves as a live illustration of trade-offs in an industrial setting. The full tool cannot be demonstrated as it involves heavy computations and a high performance computing environment.

Research questions:

- Heterogeneous environment combining cellular with WiFi; , it is possible to shut-down some of the hot-spots of Wi-Fi but not shutting down some parts of the cellular network . Traffic prediction may help but is rarely good. Cellular alone covers non-peak situations where you don't need the wi-fi off-loading. It is easier to shut down and put back the wi-fi hot-spot than a Base Station. Energy-efficiency has to be carefully calculated
- Note: Public networks cannot be shutdown; it is no good idea to leave areas without coverage. It is not easy to shut down base stations , as in wired networks. Debate on "closing the Base Station " and why it is not so easy as to turn-on/off a switch. Much more complicated than it seems.

PANEL (A): How to migrate end users to adopting Green ITC technologies

Ideas and key findings during the debate:

- Education, especially in the case of young people, seems to be a crucial factor when it comes to migrate end-users towards adopting Green ITC technologies.
- Culture has also a high impact in the behavior of end-users. Western cultures do not reuse, they just buy and throw away technologies. Manufacturers prefer to sell than to repair, and repairing services in Europe are usually bad and expensive. Also, some European countries tax the extended usage of old technology. On the contrary, Eastern cultures are more used to fix things than to resupply and have better repairing services.
- Also, culture has a high impact on the sharing concept. People belonging to American and European countries hardly share technology. They just buy for themselves and don't want to share. Eastern cultures have a higher sharing background. Technology sharing seems to be a good way to migrate users to greener behaviors.
- Users could have more green behaviors if they were better informed and also more honestly. Nowadays, it seems that nobody really knows how much energy a certain technology consumes. It would be good to promote dissemination strategies that arrive to people, so that they can take informed decisions on how to make their main investments (education, housing, transport...) from the green point of view.

- Consumers seem less willing to pay more for Green ITC, than they do for green housing (around 20%). One of the main reasons might be that people don't know how to calculate the long-term energy consumption. They sometimes prefer not to overspend when paying for a product or service, without caring for its emissions life-cycle.

PANEL (B): How should computing industry prioritize and plan over time migration to Green Computing?

Ideas and key findings during the debate:

- Industry usually considers the "greening action" as an internal effect only, not caring for society wide effects. If they apply the greening concept, they expect to reduce the operational costs, or just get access to some kind of investment / subsidy. They can consider greening actions as: (i) a business (buy green), (ii) a service or (iii) as a social service.
- The main-players are often 2-3 big companies, which generate a monopoly situation. If Google, Microsoft, etc do not make steps, no-one will. In communications, Ericsson and Huawei are much more active in concrete terms. The return to society, and CSR (Corporate Social Responsibility) should also be taken into account.
- In general, in Green ITC area telecommunications and building sector (insulation) fare best, followed by utilities, and worst are computing/ computers/data centers and consumer electronics
- An option would be to make companies drive an agenda out of self-benefit, which is, letting them decide what the best is for them. This way, there would be some early adopters of new technologies who would be followed by the others by a snowball effect.
- There seems to be also some benefits for the users of dealing with the green companies. In the case of mobile communications, for example, you can optimize the access network so that users can access services more efficiently and have more battery lifetime on their smartphones.
- It's difficult for users to identify what products are "green". "Green Washing": users will expect better batteries in laptops, smartphones, etc. → they get used to utility and usability → would users care about batteries types because of their sustainable

life-cycle impact? Or because they are greener? Would they care about the energy footprint of the batteries?

- Could users advise companies about greening and companies inform users (explain them what they do).
- There are substantial differences amongst countries regarding environmental laws. In some countries they are useless (citizens or social interests groups don't want them); whilst in other countries industries companies not doing anything about greening can be seriously fined.
- It's better to refurbish or keep something from the energy-efficient point of view than just buying something new (has carbon emissions, goes to china, comes back, etc.). Tradeoff between buying new (consumes less energy) vs. keeping old and refurbishing at the occasion of upgrades (eliminates fabrication energy footprint)