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Abstract:

This document is the first deliverable of the new WP21 on Green Optical Networks. This report contains the planned activities into the BONE project in 2009 and 2010.

At the time of submission of this Deliverable there are thirteen partners involved in the 6 joint activities that have been proposed in this workpackage, and several mobility actions are planned.

Keyword list:

Energy efficiency, power consumption, carbon footprint, GHG emissions, optical networks, network-wide solutions, network elements

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1. Executive Summary

This document is the first deliverable of the new Topical Project on Green Optical Networks. This report contains the planned activities into the BONE project in 2009 and 2010. The workpackage is building partially on previous activities in the BONE project in 2008, more specifically on WP21-2008 and on WP14-2008. The BONE consortium suggested to create this new Topical Project to reflect the large interest in this research topic of energy efficiency, both from the side of the European Commission and from the side of the research community. This new WP proposal was approved by the BONE Review Panel at the review meeting in Brussels (March 2009).

At the time of submission of this Deliverable there are thirteen partners involved in the six joint activities that have been proposed in this workpackage.

The topics covered by this WP will address a wide range of issues: from power consumption and power management of individual network elements and network segments, to routing protocols for energy optimization and proposals for new power strategies to improve energy efficiency.

The results of this WP will provide an understanding of the energy footprint of ICT today and in the coming decade. This will allow evaluating the relative importance of different network segments and technologies (with a focus on optical technologies) in terms of energy consumption and energy optimization and therefore to identify which technical approaches need to be further investigated.

2. Introduction

This document is the first deliverable of the new Topical Project on Green Optical Networks. This report contains the planned activities into the BONE project in 2009 and 2010. The workpackage is building partially on previous activities in the BONE project in 2008, more specifically on WP21-2008 and on WP14-2008.

In sections three and four, this report provides a list of the partners involved in the workpackage as well as the joint activities in which they are involved. Section five focuses on the more detailed description of the joint activities.

3. Participants

There are thirteen partners collaborating in this work package. Table 1 shows the list of participants involved. A detailed description of the joint activities is provided in the following chapter.

Partner No	Member
1	IBBT
2	TUW
18	GET
19	AIT
23	UOP
24	BME
27	FUB
30	POLITO
31	SSSUP
33	UNIMORE
41	KTH
47	UEssex
48	USWAN

Table 1: Work package participants in the WP21 joint activities

4. Workpackage structure

No	Joint Activity Title	Responsible person	Participants	Deadline
1	Estimating the Footprint of ICT and Identifying the Main Contributors	Mario Pickavet (IBBT)	IBBT, GET	M24
2	Power Consumption and Supply of Individual Network Elements	Slavisa Aleksic (TUW)	TUW, BME, PoliTo, UNIMORE, UoP, USWAN, FUB	M36
3	Energy Saving Potential by Selective Switch-off of Network Elements	Fabio Neri (PoliTo)	PoliTo, KTH, FUB, IBBT, TUB, GET, AIT, SSSUP	M36
4	Green Routing Protocols	Reza Nejabati (UEssex)	UEssex, GET, KTH, AIT, SSSUP, FUB	M36
5	Innovative Powering Strategies by Renewable Sources	Michel Morvan (GET)	GET, AIT, FUB	M36
6	Energy Efficient Optical Network Design	Anna Tzanakaki (AIT)	AIT, KTH, UoP	M36

Table 2: Summary list of the planned joint activities

5. Joint Activities

5.1 JA1 Estimating the Footprint of ICT and Identifying the Main Contributors

5.1.1 Participants:

IBBT (Mario Pickavet - Mario.Pickavet@intec.ugent.be, Willem Vereecken - Willem.Vereecken@intec.ugent.be), GET (Bruno Fracasso - bruno.fracasso@telecom-bretagne.fr, Philippe Gravey - philippe.gravey@enst-bretagne.fr)

5.1.2 Responsible person:

Mario Pickavet (IBBT)

5.1.3 Description:

Today's ICT realizes many energy-reducing measures, through communication services replacing energy-greedy processes. A typical example of this is the replacement of multiple flights to a common meeting place by tele-conferencing. On the other side, it is becoming clearer that ICT demands significant energy consumption on its own in our society. This growing consciousness, together with the ever rising energy prices and EU initiatives to reduce the emission of greenhouse gases drastically in the next decade, is urging for research efforts on green networking.

To get a clear view on the energy footprint of ICT, it is important to investigate the worldwide situation today and the expected trend in the coming decade. Not only the use phase of ICT equipment, but also the (energy-intensive) production phase must be taken into account. The energy efficiency of various communication media like optics, electronics, wireless, etc. will be comparatively studied. The power consumption of terminals (e.g., personal computers) and of the network infrastructure (e.g., switches and routers) will be estimated, and possible power-aware architectures for these devices will be proposed.

Special attention will also be paid on the deployment, power consumption, and overall life cycle of home networks, which is already one the main contributors to the overall footprint of ICT. Considering the huge mass of statistics and reports provided in that framework by different operators, manufacturers, and independent experts, the idea is here to determine appropriate metrics considering the type of service, the number of consumers and the geographical kWh/CO2 rate.

5.1.4 Outcome of the joint research activity:

The first goal of this joint activity is to construct a thorough, objective and comprehensive estimation of the footprint of ICT today and in the coming decade. Secondly, the main contributing factors/technologies/equipment types will be identified. This will allow to judge the relative importance of different network parts in terms of footprint and hence to identify which categories to investigate further. It will also allow providing guidelines on suitable and less suitable technological solutions from a footprint point of view.

5.1.5 Targeted call for papers:

Due to the special nature of this joint activity, organization and attendance of specific sessions/workshops/symposia on energy efficiency at technical conferences (ECOC, OFC, ICC, Globecom, etc.) will be crucial. Contribution to these events in terms of publications will also be pursued.

5.1.6 Deadline:

This JA runs from Jan. 2009 until Dec. 2009. As it will provide valuable input to the other joint activities in this workpackage, the effort is concentrated in the first year of the Topical Project WP21 on green optical networks.

5.2 JA2 Power Consumption and Supply of Individual Network Elements

5.2.1 Participants:

TUW (Slavisa Aleksic, Slavisa.Aleksic@tuwien.ac.at), UPCT (Pablo Pavon, Pablo.Pavon@upct.es), BME (Szilárd Zsigmond, zsigmond@tmit.bme.hu), PoliTo (Fabio Neri, Fabio.Neri@polito.it), UNIMORE (Maurizio Casona, maurizio.casoni@unimore.it), UoP (Tanya Politi, tpoliti@telecom.ntua.gr), USWAN (Karin Enser, K.Ennser@swansea.ac.uk), FUB (Francesco Matera, mat@fub.it)

5.2.2 Responsible person:

Slavisa Aleksic (TUW)

5.2.3 Description :

Power dissipation is a very important task when planning and designing network elements.

On one hand, it is expected that switches and routers within the core area will need to be highly reliable and support very high capacity of hundreds of Terabits or even several Petabits throughput in the near future. The power consumed by large switches and routers has been increasing with the overall switching capacity, and has become one of the most stringent limits to the design of larger switches. The expected increase of line rates to 100 Gb/s will further stress these limits. Beyond monitoring the scaling trends of current commercial switching devices, it is important to identify switching architectures and protocols to minimize their power consumption. A significant advantage of optical technologies with respect to electrical technologies is better scaling of power consumption when information is transmitted and/or switched at increasing bit rates and at longer distances. Indeed, a strong driver for the successful deployment of fiber optics in telecommunication has been a reduced need for power supply, e.g. in submarine cables, or in WDM long haul links.

On the other hand, in the access area, the current growth of the number of users and the average bandwidth per user set new requirements on implementing and maintaining such highly heterogeneous networks with a high number of network termination points. Thus, the increased capacity and introduction of new technologies will open new questions and problems related to power consumption and supply as well as protection.

Concerning power consumption some fundamental aspects regard the access networks where the most expensive investments will be carried in next years. Optical fibre to the home/building is a well accepted solution for high density inhabitant locations, conversely, in the opposite case the use of copper (VDSL) and radio is still under exam, especially for rural regions. These choices should be analyzed also from the energy consumption point of view since xDSL and radio solutions have a higher power consumption with respect to technologies based on optical fibres.

This JA aims in estimation of power consumption of different structures of network elements for future optical networks that are based on various transmission and switching technologies (electronic/optical/hybrid implementation, circuit/packet/burst switching, different architectures). Moreover, options for uninterruptible power supply systems (UPSs), battery backup, and alternative energy generation and storage will be examined.

TUW and PoliTO have experience in optical and electronic switch/router architectures as well as in issues related to power consumption.

FUB has experience in analyzing cost planning for access networks (xDSL, FTTx, radio) and therefore can carry out investigation also on energy consumption of access infrastructures.

In this JA FUB can make an investigation on power consumption in some access environment supposing different architectures and report an investigation among xDSL, radio and FTTx solutions, taking into account for an instance the current Italian access situation. PoliTO will analyze the power consumption of commercial switches, routers and cross-connects to extrapolate scaling laws for the power consumption of different classes of switching devices.

5.2.4 Outcome of the joint research activity:

Joint publications and eventually a database of power consumption and supply options for different architectures and technologies can be created.

5.2.5 Targeted call for papers:

It is envisaged that the results of this work will lead to one journal and one conference publication.

5.2.6 Deadline:

Timescale: January 2009 – December 2010.

5.2.7 Remark:

This JA is under the common umbrella of the workpackages WP14 (Virtual Centre of Excellence on Optical Switching Systems) and WP21 (Topical Project on Green Optical Networks), providing the bridge between both domains. This positioning is crucial to allow for input from optical switching systems experts into the WP21 activities on power consumption.

5.3 JA3 Energy Saving Potential by Selective Switch-off of Network Elements

5.3.1 Participants:

PoliTo (Fabio Neri), KTH (Paolo Monti, Lena Wosinska, Jiajia Chen), FUB (Francesco Matera, Angelo Coiro), IBBT (Bart Puype, Mario Pickavet), TUB (Ahmad Rostami, Filip Idzikowski), GET (Philippe Gravey / Bruno Fracasso / Frédéric Lucarz / Michel Morvan), AIT (Anna Tzanakaki, Kostas Katrinis), SSSUP (Isabella Cerutti)

5.3.2 Responsible person:

Fabio Neri (PoliTo)

5.3.3 Description:

Telecommunication networks and the Internet are normally planned and controlled with the aim of minimal utilization of available resources (switching points, transmission links, on-line regenerators, etc.). Resources are typically over-provisioned, hence network resources are operated at quite low loads. The recently increased attention towards energy saving in telecommunication networks may however change these habits. While the widespread attitude today is to have the whole network infrastructure (ADSL lines, wireless base stations and access points, switches, routers, links, protection resources) permanently powered, and user terminals sporadically switched off when not used, a more conscious powering strategy for network devices may lead to significant savings in energy consumption (consider that a telecom operator easily uses some TWh per year). This is particularly true if variations on the traffic levels between day and night, and between work days and vacation days are properly exploited in a dynamic fashion.

In a energy-aware (or “green”) network, the operation criteria should be changed from evenly spreading traffic over available resources for congestion minimization to concentrating traffic on the minimal subset of available resources that guarantee service delivery with the desired quality level. In the latter case, part of deployed resources can be powered-off or kept in a low-power stand-by mode, thereby reducing energy consumption. This policy can be effectively applied also to protection resources, possibly loosening the requirements in terms of fault recovery latencies.

While the observations above are true for all network technologies, optical technologies can play a significant role in greening telecommunication infrastructures, as they scale, in terms of power consumption, better with the capacity × distance product with respect to electronic counterparts.

This JA will study the advantages in terms of power consumption achievable in optical networks by selectively and dynamically switching off network devices and user terminals.

Possible research areas will be:

- power-aware Routing and Wavelength Assignment (RWA) in wavelength routing networks: fiber links and full cross-connects can be powered off if light-paths are preferentially routed over active resources
- estimation of the possible savings in current networks by routing the traffic on the minimal subset of resources that can provide the desired quality of service (joint routing and topology design to minimize power consumption)
- definition of management protocols to control the powering state of network devices and their subsystems
- define strategies to selectively switch off inactive coverage cells in wireless-over-fiber (WoF) and optical wireless access/home networks
- evaluate power savings attainable when the network periphery is switched off
- assessment of the savings that can be obtained by powering off parts (e.g., ONUs) of passive optical networks (PONs), and definition of new, energy-efficient PON architectures

- investigation of the optimization of transmission elements to save energy, taking into account the exploitation of the transmission capacity of optical fibre systems to reduce the use of devices as 3R regenerators

The partners involved in the JA will bring specific and complementary expertise to the overall picture.

- PoliTO will be active in three directions. The first one is the implementation of a distributed system to control the powering state of user terminals (www.polisave.polito.it), which has already been deployed within the Politecnico di Torino campus network. The second one is the optimization of routing within given topologies with the goal to power off the largest possible number of devices. The third one will be the definition of power-aware RWA heuristics.
- KTH contribution to this JA will be mainly focused on the following aspects: (i) energy efficient design of PON architectures, and (ii) routing and topology design approaches to reduce power consumption.
- FUB will make simulations, based on OPNET code, on transport networks based on MPLS/SDH nodes looking for solutions with the aim to save energy. FUB will test by means of numerical simulations some environments that have previously been analyzed from an analytical point of view.
- IBBT will study strategies to switch-off network elements during low-load hours and the routing adaptations that are needed as a consequence.
- TUB will investigate the potential saving of energy that can be achieved by adapting the virtual topology and IP routing in an IP over WDM network to the changing traffic demands; specific focus will be on the line cards as the network elements that can be potentially switched off.
- GET Bretagne will estimate the potential energy saving that can be obtained by selectively switching off inactive coverage cells in pico-cellular wireless-over-fiber and optical wireless access/home networks, both for indoor and for outdoor scenarios.
- AIT will investigate the impact of resilience capacity requirements in the energy consumption of WDM optical networks. The proposed work will focus on potential energy saving through switching-off of equipment supporting resilience requirements as appropriate.
- SSSUP will study scheduling strategies for switching off network elements, in order to follow the changes in traffic patterns, energy consumption or clean-energy production. Reliable routing will also be accounted.

5.3.4 Outcome of the joint research activity:

The competences of contributing partners will be integrated in the JA, exploiting the complementary of know-how. The outcomes will be algorithms for energy-aware design and operation of networking infrastructures, and the assessment of the power savings enabled by those algorithms.

5.3.5 Targeted call for papers:

To be identified among the best networking conferences and journals, and within the several new conferences and workshops specifically targeting green networking.

5.3.6 Deadline:

End 2010.

5.4 JA4 Green Routing Protocols

5.4.1 Participants:

UEssex (Reza Nejabati), GET (Philippe Gravey), KTH (Paolo Monti), AIT (Anna Tzanakaki), SSSUP (Alessio Giorgetti), FUB (Francesco Matera).

5.4.2 Responsible person:

Reza Nejabati (UEssex)

5.4.3 Description :

The energy efficiency in Networking and IT can be pursued along two main directions: the reduction of energy consumption (energy efficient solutions) and the deployment of renewable energy sources (green solutions). The new generation of carrier-class network equipment available on the market, are equipped with CPUs and electronics that stabilize their energy budget. For example, modern telecom routers use a reduced and fixed amount of energy regardless of their traffic load. Moreover, the continuous miniaturization in optical and electronic components allows packing equipment in less cumbersome racks, thus reducing their operational energy consumption. For further optimization of energy consumption, an energy-aware resource allocation/selection strategy and associated algorithms can play an important role.

This JA will study novel energy aware routing protocols and algorithms in which the energy optimization is the main objective for path computation and in turn network and IT resource provisioning and allocation. It focuses on investigating routing algorithms, protocols and procedures at both layer1 (optical) and layer 2(carrier grade Ethernet) taking to account several factors important for energy consumption such as node characteristics (e.g. optical transparency), geographical location of nodes and links, instantaneous load of the nodes, length of the links as well as considering bit-rates, loss and other physical layer impairment requirements. In particular the possible implementation of the proposed routing algorithms will be investigated in GMPLS-based networks by means of proper extensions of the current GMPLS protocols. Furthermore, Mesh and interconnected-ring topologies will be considered as well as partly transparent optical nodes.

5.4.4 Outcome of the joint research activity:

The outcome of this activity will be joint publications where different layer1 and layer 2 routing protocols with extensions to support energy optimization will be reported and their performance will be investigated.

5.4.5 Targeted call for papers:

Journals: IEEE JOCN; Conferences: Globecom 2010, OFC 2011

5.4.6 Deadline:

End 2010.

5.5 JA5 Innovative Powering Strategies by Renewable Sources

5.5.1 Participants:

GET, AIT, FUB

5.5.2 Responsible person:

Michel Morvan (GET)

5.5.3 Description :

Powering strategies have to be differentiated between network elements and network themselves. Unlike core networks, access networks may have various needs in terms of power and various constraints in terms of network dependability. Network dependability is not homogeneous and does not strain powering strategies equally. We then propose to focus on access networks and define a simple model to describe the day-time dependence of the network power consumption.

Innovative powering strategies for large sets of remote units in optical fibre or hybrid RoF networks will be investigated. Optical powering techniques, renewable sources of energy (solar, wind) together with extensive use of “sleep mode are some possible solutions.

For an instance it has also to be pointed out that the links that have to be switched on in conditions of higher traffic can be efficiently fed with solar cells, since the traffic load occurs mainly during the day time. For an instance, panels of some square meter can feed central for some kW. Therefore, a suitable project that takes into account both the reduction of transmission elements and the use of renewable energies, can give an important contribution in terms of no renewable energy saving.

Opportunistic powering strategies based on the use of existing power sources belonging to other facilities will be also investigated. For instance the use of the electrical powering of the lighting network in urban and semi-urban areas can be envisaged. Power mutualisation has to be looked for in order to optimize overall cost and investments.

5.5.4 Outcome of the joint research activity:

Joint publications, mobility actions

5.5.5 Targeted call for papers:

Conferences: Globecom 2010, OFC 2011

5.5.6 Deadline:

End 2010.

5.6 JA6 Energy Efficient Optical Network Design

5.6.1 Participants:

AIT (Anna Tzanakaki, atza@ait.edu.gr), KTH (Lena Wosinska, wosinska@kth.se), UoP (Tanya Politi, tpoliti@uop.gr)

5.6.2 Responsible person:

Anna Tzanakaki (AIT)

5.6.3 Description:

The issue of Energy Consumption is a central point of attention in several industries. Recently it started attracting a lot of attention in the context of network equipment and networking in general. This is due to the fact that, although today the total energy consumption of the Internet is only a very small percentage compared to the levels of power consumption required in other industries, it is rapidly expanding directly influencing the relevant ratios. In addition, in the context of networking issues associated with equipment and therefore energy density may also be important.

This JA aims at addressing the issues of energy consumption in optical networks by including it as a major consideration at the network design stage. This involves detailed network planning and dimensioning taking into account traditional considerations relating to cost-efficiency and capacity availability but it will also include energy-consumption as an additional constraint. Following this approach a detailed analysis on achieving optimum network performance with energy and cost efficiency can be produced and any required trade-offs can be identified and studied. This energy-efficient planning approach will be based on realistic equipment power consumption figures available in the literature and network equipment specifications and relevant models will be produced.

AIT has expertise in network modelling, network design/dimensioning, cross-layer constraint routing, as well as resilience and service provisioning in optical networks.

KTH has expertise in design, control and management of optical networks with particular attention on cost and energy efficiency, solving network optimization problems and techno-economic studies

UoP has expertise in network modelling and constraint based routing in optical networks as well as energy efficiency studies in the context of optical network equipment.

5.6.4 Outcome of the joint research activity:

Researcher exchanges and joint publications. It is envisaged that the results of this work will lead to one journal and one conference publication.

5.6.5 Targeted call for papers:

OFC 2010 October 2009 or ECOC 2010 March 2010

5.6.6 Deadline:

End 2010