Power Considerations for ICT Sustainability: the GEYSERS Approach

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As the scale of information processing is increasing, from Petabyes of Internet data to the projected Exabytes in networked storage at the end of this decade [1], [2], novel network solutions are required to support the Future Internet and its new emerging applications such as UHD IPTV, 3D gaming, virtual worlds etc. These high-performance applications, requiring very high network capacities and specific IT (e.g. computing and data repositories) resources, cannot be intrinsically delivered by the current Best Effort Internet. On the other hand, optical networking is offering a very high capacity transport with increased dynamicity and flexibility through recent technology advancements including dynamic control planes etc. In this context, the European project GEYSERS (Generalised Architecture for Dynamic Infrastructure Services) is defining and implementing a novel optical network solution, capable of provisioning "Optical Network and IT resources" for end-to-end service delivery.

At the same time it is estimated that Information and Communication Technology (ICT) accounts for 4% of the primary energy consumption worldwide [3]. The expansion of the Internet in size and complexity incurs increased energy consumption of both IT and network resources, thus attracting a lot of attention on energy efficient networking [4]. Designing, engineering and operating infrastructures comprising IT resources and optical networks in a power-aware manner seems to be instrumental for a more energy-efficient and hence sustainable ICT. It is true that IT resources require very high levels of power for their operation and their conventional operating window is commonly not optimized for energy efficiency. Hence, allocating IT processing jobs in an energy-aware manner through a relatively low energy-consuming optical network infrastructure is expected to offer significant energy savings. On the other hand, although optical networking is an energy efficient technology to use, it has been shown [4] that the system design itself cannot fulfill the needs for limiting the overall power consumption, thus network design and protocol implementation have to also become power-aware.

Following the increasing interest in energy-efficient infrastructures, GEYSERS is proposing a complete solution facilitating energy efficient operation of infrastructures incorporating integrated optical network and IT resources. More specifically GEYSERS is focusing on the concept of Virtual Infrastructures (VIs) over one or more interconnected Physical Infrastructures (PIs) comprising both network and IT resources. The introduction of VIs in this context facilitates sharing of physical resources among various virtual operators, introducing a new business model that suits well the nature and characteristics of the Future Internet and enables new exploitation opportunities for the underlying physical infrastructures.

In the GEYSERS layered architecture (Figure 1), devices in the PI layer are abstracted and partitioned or grouped into virtual resources that can be selected to form the Virtual Infrastructures in the Logical Infrastructure Composition Layer (LICL). Within each VI, controllers in the IT-aware network control plane (NCP+) layer configure and manage virtual network resources, while virtual IT node controllers at the Virtual IT Manager (VITM) control the virtual IT resources. The Service Middleware Layer (SML) is responsible for translating the application requests and service level agreements (SLAs) into technology specific requests to trigger the provisioning procedures at the NCP+.

In GEYSERS energy efficiency is targeted, in an integrated IT and optical network infrastructure, taking a multilayer approach. GEYSERS is inherently addressing the issue of energy efficiency, given its focus on optical network technology that has been proven to be significantly more energy efficient than alternative network technologies [5]. However, additional energy efficiency considerations are addressed in both the VI planning and the VI operation/service provisioning phases taking into consideration the combined energy consumption of both optical network and IT resources.

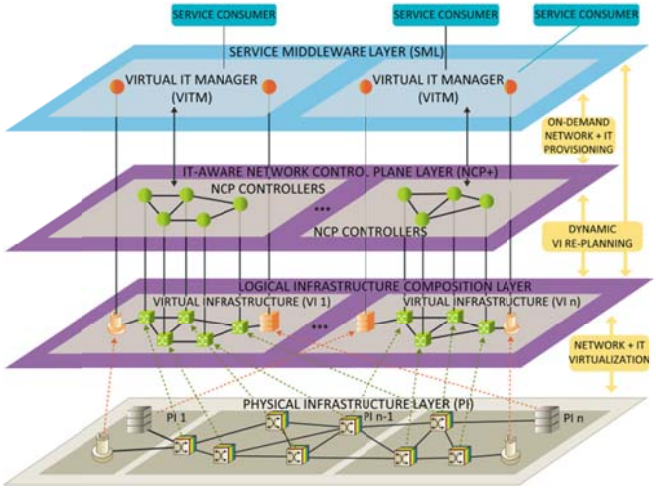

Figure 1: GEYSERS layered architecture

Regarding the VI planning phase the responsible layer is LICL. The objective of VI planning is to implement a dynamically reconfigurable virtual network that satisfies the virtual infrastructure requirements, while maintaining the specific need of energy efficiency. Through this process the least energy consuming VI that can support the required services is identified in terms of both topology and resources. To discover this least energy consuming VI the detailed power consumption models and figures of the underlying physical infrastructure, including joint consideration of optical network and IT resources, are taken into consideration. Mapping the virtual resources to the physical resources is also part of the VI planning phase. Therefore the VI planning phase is also responsible to define the energy consumption parameters of the VI itself. Through the VI planning process, virtual resources will be effectively abstracted from the physical devices and will be marked with "green parameters". Using these parameters, the virtual infrastructures can be operated in an energy-efficient manner, through the implementation of energy-aware provisioning mechanisms at the NCP+ layer.

The GEYSERS NCP+, based on the ASON/GMPLS and Path Computation Element (PCE) architectures and protocols, is playing a key role in the operational energy efficiency of VI infrastructures. In the effort to maximize the energy efficiency of operating VIs, the NCP+ can compute end-to-end paths with an objective different from those considered in conventional approaches (e.g. length-based, or hop-based shortest path etc.), such as the minimization of the energy consumption associated with the corresponding services taking into account the "green" parameters, describing the power consumption of the heterogeneous resources involved. To further increase the energy saving during the operation of the VI the option of switching-off unused resources (network and IT) is also proposed. This approach involves the introduction of a sleep or stand-by mode during which unused resources can be set to and awaken from in a fast and seamless manner, when required to be used. In addition, in the GEYSERS architecture the LICL dynamically and continuously synchronizes the energy status of physical resources and their associated virtual resources. Therefore, in case of energy inefficiency situations a VI re-planning phase can be initiated.

Initial modeling results indicate that the proposed energy efficient approach addressing both the design and operation of integrated optical network and IT infrastructures achieves significant energy savings [6] and these become more substantial when service resilience is also taken into account. Considering the relevance and impact of the proposed approach in the context of Future Internet and the sustainability of the ICT as well as the quantification of the associated benefits, it is expected to attract significant interest and attention.

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