Energy efficient slicing for 6G networks using AI/ML technics

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Topic.
With the current energy crisis, the skyrocketing cost of energy, and the global awareness of the consequences of carbon emissions on our planet, it is crucial to reduce the global energy consumption related to Information and Communication Technologies, and in particular the one related to networks.

Indeed, while being commercialized worldwide, the 5G technology coupled with ultra high resolution video has been blamed for its high energy consumption [5G-power]. To answer this issue, industrials and researchers have started to look beyond 5G to define the next 6G with at its core the need to evolve towards greener networks. The 6G standard imposes a **transmission energy efficiency target** in its Key Parameter Indicators (1picoJ/bit). However, at the same time, 6G will introduce several technological breakthroughs with the integration of traditional terrestrial mobile networks with emerging space, aerial, and underwater networks to provide anytime, anywhere, network access. Another critical paradigm of 6G is the utilization of **Artificial Intelligence (AI) techniques** to provide context-aware information transmissions and personal-customized services, as well as to realize automatic network management [roadmap]. The growing ICT infrastructure, exploding data, and the AI-based services will result in surging energy consumption.

Thus, succeeding in the challenge of developing more energy efficient networks will require significant improvement in several directions [survey-green]: e.g. re-launching measurement campaigns, rethinking protocols, developing energy-efficient network management algorithms [algo], adopting energy harvesting techniques [harvesting], deciding if and when data should be sent, but also creating tools to allow the individuals to take informed decisions and have a sustainable Internet usage, in particular with the high definition video traffic.

We will focus on the **provisioning and management of energy efficient network services.** With the advent of next generation networks implementing Software Defined Networks (SDN) and Network Function Virtualization (NFV), network services can be set up dynamically at the right time and at the right place. It has been shown that SDN can improve the energy efficiency of networks by allowing fast rerouting. This allows to turn off redundant parts of the networks used for backup in case of failures or over-dimensioning in case of sudden peaks of traffic [sdn-energy] but also to reconfigure the network when the demand has changed [reconfiguration]. The use of virtualization also reduces the use of specialized and energy-intensive middleboxes and to provision network and data center resources only when and where needed [nfv-energy].

However, with the multiplication of usages, connected cars, cities, factories, more generally with the development of the Internet of Things, the number of services a network has to handle increases drastically. At the same time, with the consideration of micro-services composed to build network functions which are then added to form network services, the size of the latter also increases. New methods have to be considered to be able to provision them on the fly in a **fast and scalable way**, while not increasing network energy consumption.

During the PhD we will tackle theses problems following the guidelines written below:

- First, we plan to **refine existing power models** as there are the foundations to discuss energy efficiency. We will make a special focus on video services, as video represents the majority of the Internet traffic and drives a significant share of the investment in terms of data centers and Internet links. We will start from the methods proposed in [power-models] proposed methods to estimate the carbon footprint of a typical streaming service.

- Second, we plan to explore how to use **new AI methods** for this challenge. AI/ML methods are envisioned as a way to progress towards green networks [AI-for-green]. In particular, new learning methods have been proposed to solve large scale combinatorial problems, some of which are at the core of network placement problems. As an example, [NIPS-billion] presents a reinforcement learning method to solve covering problems for billions-sized graphs. This RL method has a good potential to help provisioning network services, as placing services can be seen as a covering problem, see [covering]. We will thus investigate how to use these new AI methods to provide approximate solutions for provisioning a very large number of network services.

- Third, we plan to study how AI models can help to **reconfigure the networks efficiently** when (i) demand or (ii) energy availability has changed. (i) First, the level and nature of traffic strongly vary during the day. Second, with the development of smart cars, UAVs, extra-terrestrial networks, there will be a high mobility of end-nodes. Network services will thus have to be sufficiently instantiated, reconfigured, and stopped within a short time scale. (ii) Indeed, energy harvesting has been widely recognized as an important part for green communications. Part of such energy resources is uncontrollable but predictable (such as solar, winding, tide, and other renewable sources). Another part is partially controllable such as Radio Frequency energy harvesting [harvesting]. Another issue that will be faced during next winters in Europe concerns planned power cuts. The challenge is to find ways to manage the networks and the expected demands with such varying sources of energy? We will study how AI models using energy predictions can allow reconfiguring the network in advance to adapt to the changing energy availability, e.g. to choose when doing a large backup, to plan the switching off of some network parts.

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