

1. Background and project topic relevance

Teleinformatic networks are an indispensable part of society's life, supporting various branches of people's activities – from entertainment and social life to finances, business, and education. Their highly relevant role and increasing popularity trigger a fast development of network technologies, especially software solutions controlling their operation and mechanisms providing resilience (protection against failures and attacks). The most promising direction of their development is now the network management and control based on a continuous observation of network state and application of advanced algorithms (including machine learning) for decision-making based on the gathered data and constructed network state forecasting models. However, the extremely fast development of networks and their controlling systems brings various challenges, which should be appropriately addressed before implementing new proposals in real networks. The first challenge is **excessive energy consumption and greenhouse gas emissions**. The ICT industry was responsible for 4% of global energy consumption and 1.4% of global greenhouse gas emissions in 2020. It is a 5% increase compared to 2015ⁱ. Fast network development entails an increase in the number of installed networking devices that consume electricity. What is more, the algorithms used in modern network controlling systems are increasingly complex and computationally expensive. It is also intensified by the high popularity of deep learning approaches. The mechanisms used actually to reduce energy consumption and emissions are not sufficient enough and it is necessary to revisit them and propose new approaches tailored to the currently implemented technologies and control systems. It is worth mentioning that reducing greenhouse gas emissions is a crucial priority according to the European Commission's strategy. The second challenge is providing network resilience alongside **the minimization of energy consumption and emissions**. Resilience mechanisms often require extra resources and computations, which deepens the problem of excessive energy consumption and greenhouse gas emissions. Thus, it is necessary to revisit existing resilience methods and propose new ones that will simultaneously consider the energy and emissions issues. The third challenge is a **lack of understanding, full control, and trust in controlling systems based on machine learning**. As a result, the network operators avoid implementing these new and untrustworthy proposals in real networks.

2. Research objective

The project is an answer to the identified challenges in the networks' development. It aims to **design, implement, and evaluate a packet of models and algorithms allowing to design and optimize future transport optical networks – Green, REsilient, and Explainable NETworks (GreeNet)**. The green networking paradigm will be achieved by designing methods concerning the minimization of energy consumption and greenhouse gas emissions by network devices and algorithms controlling their operation. The green network resilience will be addressed by proposing dedicated mechanisms simultaneously concerning resilience, energy consumption, and emissions. Lastly, network explainability will be achieved by using explainable artificial intelligence methods to interpret and understand network operation and the decisions of machine learning-based models controlling that operation as well as to use that analysis for the models and algorithms targeted improvement.

3. Project work plan

The project is divided into four stages, each one with a list of research tasks and goals: *(i)* Selection of real network topologies for experiments and elaboration of their energy profiles (characteristics of power plants supporting network nodes (type, historical data on energy production level, energy prices and emissions), creation of forecasting models concerning energy production, prices and emissions for the selected power plants); *(ii)* Design of models and algorithms for the transport optical network design concerning minimization of energy consumption and greenhouse gas emissions; *(iii)* Design of models and algorithms for the transport optical network optimization (reconfiguration) concerning minimization of energy consumption and emissions; *(iv)* Design of models and algorithms for the transport optical network design and optimization (reconfiguration) considering simultaneously network resilience and minimization of energy consumption and emissions.

4. Expected results

The expected results will be the **development of knowledge on modeling and optimization** of optical networks as well as **practical applications of machine learning and explainable artificial intelligence**. The proposed methods will address vital aspects such as **reducing energy consumption and greenhouse gas emissions** in teleinformatic networks and **increasing their resilience, explainability and trustworthiness**. The results will be new knowledge from **computer science and telecommunication**. The knowledge may be interesting and valuable for other researchers and network engineers and may be used when designing new protocols and standards. Thus, the principal investigator will publish it in prestigious research journals and during international conferences.

ⁱ [1] Malmodin et al. "ICT sector electricity consumption and greenhouse gas emissions – 2020 outcome". Telecommunications Policy, 48(3):102701, 2024.