

Computing: Environmental impact of mobile networks

Michele Rossi, Full Professor at the University of Padova, explains what we need to know about taming the environmental impact of mobile networks through GREENEDGE computing platforms

[GREENEDGE](#) is a Marie Skłodowska-Curie research project devoted to developing innovative computing technology for our hyper-connected society, while preserving the environment. Its main goal is to reduce the carbon footprint of the edge computing technologies exploited within modern mobile networks. The computation at the network edge is key to supporting many emerging technological fields, from extended reality to smart health, smart cities, smart factories and autonomous driving. Multi-access edge computing (MEC) technology is being developed to deliver the required computation functionalities closer to user devices, directly at the mobile access points. However, the large-scale adoption of MEC technology, while benefiting human productivity and efficiency, will result in a surge of data and computation in mobile networks, which, in turn, will exacerbate their energy consumption.

GREENEDGE sets out to tame the growing carbon footprint of MEC technology, devising highly energy-efficient communication and computing functionalities for the network edge, combining them with sustainable energy sources. As a result, GREENEDGE technology will allow mobile systems to offer much-anticipated communication and computing services in an eco-friendly, sustainable manner. Fifteen Early Stage Researchers (ESRs) will be trained by world-class leaders across the fields of energy resources, edge computing, optimisation, machine learning and wireless

communications. Ample inter-sectoral opportunities will be offered thanks to secondments among academy and research centres, two network operators, and other prominent industrial partners.

Vision

Mobile communications pervade our everyday lives, deeply affecting the way we work, travel and spend our free time. Fifth-generation (5G) and beyond 5G networks are expected to lead to a further revolution, enabling ubiquitous and enhanced broadband services, smart/autonomous vehicles, intelligent transport and complex human-machine interactions (for example, extended reality). Similarly, the Internet of Things (IoT) trend will lay the foundations of future smart cities, Industry 4.0 and e-health environments. The GREENEDGE project rests upon the knowledge that such a connected society will generate a vast amount of data: CISCO estimates Internet traffic will increase up to 805 ZB by 2021, with an annual growth rate of 20.6 ZB. Secondly, exploiting such massive amounts of data will require significant computing resources, which is the key driver for the booming field of artificial intelligence (AI), and machine learning (ML). GREENEDGE rests on the observation that data and computation, while providing tremendous benefits by improving human productivity and social efficiency, makes mobile networks even more energy hungry, resulting in a huge and unsustainable system.

Multi-access Edge Computing (MEC) as a response to increased data production

To meet the rate and latency requirements of emerging AI applications and services, the next milestone beyond 5G networks is represented by MEC, which amounts to performing computation at the network edge empowering base stations and other edge nodes with processing capabilities. Thus, mobile networks will switch from dedicated hardware and rigid software devoted to handling communications, to powerful, flexible, and software-defined communication and computing systems. However, moving computing processes to the edge will further exacerbate the energy consumption of mobile networks. Therefore, we advocate for proper sustainable design of the integration of edge computing into mobile networks, thus offering the anticipated communication and computing services without environmental damage. Inspired by the concept of *edge intelligence*, GREENEDGE proposes an energy-aware integrated communication and computing infrastructure, enabling distributed computing at the network edge for delivering 5G services, essential for the future connected society.

Methodology

To tackle such ambitious targets, GREENEDGE will adopt a twofold approach:

- Firstly, renewable energy resources, (for example, wind or solar power), will

be exploited to sustain the communication and computing tasks that run at the mobile network edge;

- Secondly, fundamentally new and green by-design computing and communication paradigms will be developed, wisely making use of the available communication, computing and energy resources across the mobile edge network. This entails designing novel ML/AI in-network processing techniques with a small memory footprint all the while being, trainable in an energy-efficient manner. Particular attention will be paid to distributed computing approaches (federated learning) improvements in the efficiency of computation tasks (i.e., continual learning, transfer learning, meta-learning).

This will be accomplished by setting up a training network of 15 Early Stage Researchers who will research on GREENEDGE sustainable computing paradigms. They will confront a highly cross-disciplinary endeavour, mastering the fundamentals of energy generation and storage, mobile network management, machine learning/neural networks, mathematical optimisation and distributed computing. The GREENEDGE consortium's partners have highly complementary skills, which will offer stimulating environments and facilitate the internship towards an effective research network that combines industry-based training with theoretical groundwork. Inter-sectoral research is ensured by the supervision of top-notch senior researchers and educators both from academia and industry.

The ESRs will be trained in specialised training schools and supervised by leading experts in their own fields. By the end of the project, they will be awarded a PhD and will be ready to take on prominent roles in the industry or academia, leading the design and imple-

mentation of green computing systems in the next crucial years. In doing so, GREENEDGE foresees the integration of: energy harvesting and storage solutions to gather ambient energy and use it for communication and computation tasks; ML and control theories to orchestrate the provisioning of computing resources in the most energy-efficient manner within the mobile edge; advanced algorithmic frameworks, to implement eco-friendly and distributed computation pipelines (including distributed ML over energy- and noise-limited channels).

Sustainability as paradigm

ICT is a fast-growing, ever-expanding field, paramount for improving human quality of life, societal prosperity, providing new market opportunities, and opening new technological and economic sectors.

However, huge sustainability issues arise from the deployment of this cluster of technological innovations. The major ecological impact of our technology (for example, the carbon footprint) is often not considered, especially at the design stage. At GREENEDGE, we believe a sustainable development policy to be crucial; while promoting prosperity by developing and providing cutting-edge technological innovation, we will assure environment protection and ecological sustainability, in line with the goals of the United Nations Sustainable Development (UNSD) agenda.

According to the UNESCO Engineering Initiative, all engineering fields should incorporate sustainability into their practice to improve the quality of life for all citizens, not to be considered the sole responsibility of environmental engineering. GREENEDGE follows the guidelines for a sustainable design in ICT and specifically targets UN SD Goal 7 "Affordable and Clean Energy" and Goal 13 "Climate Action" by taming the environ-

mental impact of ICT with green edge computing platforms.

Moreover, GREENEDGE will contribute to Goal 9 "Industries, Innovation and Infrastructure" and Goal 11 "Sustainable Cities and Communities" through our studies on how to exploit MEC in vertical industries. In line with Goal 17 "Partnership for the goals", GREENEDGE will implement its program through a set of training schools, scientific workshops, public events that will give our ESRs a chance to develop technical skills, all the while keeping close connections with our partners, including those in the private sector, by inviting relevant stakeholders to those same events. Finally, special attention will be accorded to keeping in touch with the general public, by communicating our goals and achievements via social channels, media and public events (such as the "Researcher Nights").

There is still a significant skills gap in sustainable design in ICT. GREENEDGE is a valuable opportunity for training young talents, who will face technical, analytical and strategic problems for the sustainable design of MEC platforms to respond to future challenges and needs.



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