Doctoral School of Information and Biomedical Technologies
Polish Academy of Sciences (TIB PAN)

SUBJECT:

The analysis and modelling of energy storage systems for off-grid base stations

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DESCRIPTION:

The analysis and modelling of energy storage systems for off-grid base stations is a crucial aspect in the rapidly evolving mobile communication infrastructure.

Recently, mobile network operators have been compelled to deploy denser mobile radio access networks to deal with the exponential increase in user and data traffic due to the rapid demand for mobile networks and IoT services, resulting in a steep and steady growth of telecommunication. The growth trend in the mobile communication sector is being sustained by falling prices of user devices (laptops, tablets, mobile phones, and IoT sensors/actuator devices), evolution in mobile applications (Android and iOS-based applications), the success of social media networking giants like Meta (formally Facebook), Google, X, (formally Twitter), and Tiktok. This growth may also be sustained with the advances in Artificial Intelligence (AI), cloud computing, and IoT technologies.

The continuous expansion of the mobile communication infrastructure has resulted in a significant increase in energy consumption, especially at the fronthaul segment of the networks, which consists of a set of base stations and transmission equipment together with other auxiliary equipment (e.g., air conditioning, lighting, etc.). The base station sites are the most energy-hungry components of mobile networks as they consume about 60-80% of the total energy of the entire network. Thus, the cost of energy is among the most significant expenses of mobile operators, and it can be optimised to ensure the financial sustainability of the operations of mobile networks. Another reason it is essential to reduce or optimise the energy consumption of mobile networks is to reduce the carbon footprint of the mobile communication industry, as mobile communication infrastructures are powered using energy from the grid generated from fossil fuel energy sources.

Also, there is a growing interest in using renewable energy sources to power mobile communication infrastructures. The renewable energy sources can be used alongside energy from the electricity grid or in a standalone configuration where the base stations are wholly off-grid and depend entirely on the energy generated by the renewable energy sources. Using renewable sources to power mobile communication infrastructure is also an approach to reduce the energy pressures from the grid infrastructure and the Operational expenditure (OPEX) of the mobile operators.

The main challenge with increasing the energy efficiency of mobile communication networks is to develop reliable energy consumption models that can be used to size the energy storage systems where excess energy harvested is stored for future use and also realistic energy models that can be used to optimise energy consumption during network planning and optimisation. As we move from one generation to another (e.g., 2G/3G/4G/5G), the energy efficiency of the systems, including the equipment at the base station sites, increases, but the massive deployment of ultra-dense 5G and IoT networks, also significantly increases energy demand and drives up the network operating costs. The approaches used to develop energy consumption models for mobile networks include empirical measures, stochastic modelling, and AI-based (e.g., machine learning) models.

The major challenge with using renewable energy to power mobile communication infrastructure is the intermittent nature of renewable energy sources. That is, the sources may not be able to generate energy at all times as the ability to generate energy is influenced by the environmental conditions. Thus, the energy generation processes from renewable energy sources are stochastic. One possible solution is to use hybrid energy generation systems, and another is to incorporate energy storage systems. The various approaches used to develop energy generation models for mobile networks include:

In a comprehensive design of a reliable off-grid base station site, the problem is to size the energy demand of the site (energy required to power the nodes), the energy storage system (ESS), and the energy generation system in such a way maximise the lifetime of the site (the time required to drain the energy stored in the ESSs) and the outage probability (the probability that after a specific time the site may be down because it is unable to generate energy and all the stored energy in the ESSs is depleted).

The thesis will contribute to the above problems, especially developing tools and models to evaluate the work of energy storage systems.

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