IEEE

International Network Generations Roadmap

-2021 Edition-

Energy Efficiency

IEEE Future NETWORKS

An IEEE 5G and Beyond Technoolgy Roadmap

futurenetworks.ieee.org/roadmap

This edition of the INGR is dedicated to the memory of Earl McCune Jr., who left us tragically and too soon on 27 May 2020. Earl was a microwave/RF guru, brilliant technologist, major industry/IEEE contributor, global visionary, keen skeptic, and all around fantastic human being. He was a major contributor to the INGR's early work on energy efficiency, millimeter-wave, and hardware. He worked for a technologically advanced yet more energy efficient world, and the contents of the INGR are a tribute to that vision. Rest in peace, Earl!

Table of Contents

Tables

Figures

ABSTRACT

This 2021 Edition of the IEEE International Network Generations Roadmap (INGR) contains a new Chapter dedicated to Energy Efficiency, which builds upon the initial white paper released in April 2020 [1]. For this purpose, the Energy Efficiency Working Group developed an analysis of the energy efficiency constraints across the whole ecosystem of the Fifth Generation "5G" and following network infrastructure, which can be leveraged by all stakeholders to prioritize resources allocation and technology development to ensure that both technical and economic forecasts can be met. The complexity of the ecosystem and the traditionally siloed approach within the Industry has often prevented the adoption of a holistic approach to addressing the fundamental problem of energy, which is the ultimate constraint to any complex deployment. The proposed framework facilitates an assessment of bottlenecks and their implication on the network: it may be used by both academic and industry stakeholders to develop solutions that address the real issues and enable a healthy ecosystem.

After a comprehensive survey of the ecosystem and its challenges, the following key areas were selected for a more in-depth analysis:

- Network Efficiency
- Small Cell Migration
- Base Station Power
- Economic Factors
- Grid/Utility

This Chapter also identifies the need for a comprehensive "Systems-of-Systems" (SoS) analysis to address the complex inter-relations among the multiple layers, which the infrastructure leverages. An initial proposal describes how a model can be built to enable a comprehensive assessment of energy requirements across such a diverse ecosystem. A future step in the process will consolidate a proposal for standardization of this model, which can be utilized by all stakeholders for both analysis and forecasting of capabilities and return on investment.

Key words:

Energy Efficiency, 5G Energy Gap (5GEG), Power Value Chain (PVC), Power Cost Factor (PCF), Systems of Systems (SoS), Energy Harvesting (EH), Sustainable Power, Embodied Energy, 5G Economic Gap (5GEcG), 5G Equality Gap (5GEqG), 5G Derate Factor (5GDF), Assessment Framework