Project GAINS

(Generative AI for Network Sustainability)

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Report on the State of the Art on the Energy Impact of the Network and Cloud Infrastructure

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Abstract

This report presents the state of the art on the energy impact of network and cloud infrastructures, with an integrated focus on consumption, emissions, and measurement, modeling, and prediction methods applicable along the entire network–data center–platform chain. In a context in which the demand for digital services is growing rapidly and energy is becoming a design constraint, the most recent legislation highlights two key points: (i) the increase in traffic and capacity does not automatically translate into proportional growth in consumption due to efficiency advances, but (ii) the adoption of AI workloads and increased compute density are reopening a critical front on available power, cooling, and carbon footprint, requiring more robust and service-attributable operational measures.

The review integrates scientific contributions, technical standards, and industrial guidance to build a coherent picture of metrics and methods: from site KPIs for data centers to metrics for equipment and networks. The evidence that emerges is that efficiency cannot be evaluated only at the level of structure or datasheet: non-energy proportionality, high consumption in IDLE, and multi-vendor heterogeneity mandate a telemetry chain that combines physical and logical measurements, enables comparable benchmarking, and supports attribution per workload, slice, or service tag.

On a methodological level, the report summarizes recent surveys and taxonomies on the monitoring and prediction of energy impact in networks and data centers, highlighting the evolution from predominantly qualitative and scenario-based approaches toward data-driven and capacity-predictive integrated softwarized architectures (SDN/NFV/Network Slicing). Experimental evidence is also recalled that demonstrates significant energy savings through dynamic light path management in elastic optical networks and SDN-based strategies focused on flow consolidation and minimization of state transitions, with parameters for consumption and operational requirements.

Finally, the state of the art indicates that energy-aware and carbon-aware automation, backed by fine-grained telemetry and interoperable instruments, is the most promising lever for reducing over-provisioning and emissions while maintaining SLA, auditability, and governance. The report translates this evidence into replicable criteria for the project, proposing a “measurement-

first" approach and a set of KPIs and operational guardrails to evaluate network solutions and cloud sustainability-oriented strategies.

Table of Contents