Network Working Group
Internet-Draft
Intended status: Best Current Practice
Expires: 14 May 2026

C. Pignataro, Ed.
Blue Fern Consulting
A. Rezaki
Nokia
J. Arkko
Ericsson
A. Clemm
Futurewei
H. ElBakoury
Independent Consultant
S. Prabhu
Nokia

10 November 2025

Sustainability Considerations for Networking Protocols and Applications

draft-pignataro-enviro-sustainability-consid-03

Abstract

Embedding sustainability considerations at the design of new protocols and extensions is more effective than attempting to do so after-the-fact. Consequently, this document also gives network, protocol, and application designers and implementers sustainability-related advice and guidance.

This document recommends to authors and reviewers the inclusion of a Sustainability Considerations section in IETF Internet-Drafts and RFCs.

Status of This Memo

Copyright Notice

Table of Contents

1. Introduction

The ultimate objective of this document is to detail guidance regarding aspects of sustainability and environmental impact that authors and reviewers of Internet protocol and architecture documents should consider in a "Sustainability Considerations" section.

1.1. Terminology

This document leverages the terminology and concepts defined in [I-D.pignataro-green-enviro-sust-terminology], and readers are expected to be familiar with those. Specifically, Section 3.1.1 of [I-D.pignataro-green-enviro-sust-terminology] describes concepts of particular relevance to this draft.

2. Implications to the IETF

This section describes the implications of sustainability to the IETF. Specifically, the high-level relevant areas on which the IETF can act, and a rough prioritization. These potentially include use cases, protocols, metrics, etc.

A key area to understand the relevance and implication is regarding IETF Protocols.

3. Sustainability Guidelines for Protocol and Network Designers and Implementers

This section renders the Sustainability Considerations into specific guidelines and advice for the design and development of networking technologies.

These specific items are labeled so as to follow and reference as a check-list.

a. General:
The section title "Sustainability Considerations" should be used to detail the environmental-impact implications of protocols, architectures, and Internet technologies.

- a.1. For each of the items covered, explicitly state the "boundary of analysis" considered. For example, this can include a scope, time boundary, or lifecycle phases.

- a.2. Consider attributional versus consequential analysis methods, explaining environmental impact benefits.

- a.3. Clearly state the units used for each magnitude in every analysis (e.g., gCO_2e/kWh.)

b. Network Management:
Several areas of network management have direct relationship with sustainability.

- b.1. Metrics:
  Instrument equipment, network elements, and networks with a set of relevant and meaningful metrics that provide visibility into sustainability and environmental-impact attributes (e.g., power and energy consumption.) This is the foundation for any mechanisms to improve and optimize sustainability.

b.2. Managed Elements:
Facilitate, extend, and enrich the manageability of network elements and sub-elements which have an environmental impact, such as Power Supplies. For example, provide visibility into sourced power, e.g. energy mix, and allow to account for the "dirtiness" of power being consumed to obtain a truer picture of sustainability than can be gained by visibility into power consumption alone.

b.3. Automation and Policy Enforcement:
Network management systems should evolve from being passive observers of sustainability metrics to actively enforcing sustainability-oriented policies. Once energy consumption, carbon intensity, and other environmental data are exposed, automated systems should be empowered to make real-time adjustments aligned with operator-defined sustainability goals. For example, network orchestrators could dynamically shift workloads or traffic away from infrastructure currently powered by high-carbon sources, or initiate graceful scaling down of non-critical services during periods of high energy demand. Similarly, protocols and management frameworks could support scheduled downtimes, power state transitions, or routing policy adaptations based on thresholds related to energy efficiency, carbon emissions, or resource usage. Embedding such automation capabilities ensures that sustainability is not merely a reporting layer, but a live operational dimension that can be acted upon in-network, in alignment with business or regulatory objectives.

c. Energy Management:
Minimizing energy consumption is a critical consideration in making networks more sustainable. Minimizing energy consumption typically comes also with important economic side benefits associated with reducing operational expenses and making network providers more competitive.

To facilitate energy efficiency schemes, designers of networking devices and protocols should examine and consider the following considerations:

c.1. Energy linearity. In many cases, the amount of power drawn by a device is not in linear proportion to the volume of traffic that is passed. Instead, energy consumption when idle generally accounts for a very significant percentage of the energy consumption when under full load. The implication of this is that the volume of traffic by itself is of relative consequence to energy consumption, as long as the volume does not get to the point where additional equipment needs to be added to the network to handle peak loads.

c.2. Power saving modes. Similarly, many devices and resources support power saving modes that can be entered when idled. Similarly, during periods of exceedingly low traffic, some links may support downspeeding associated with energy savings. As a result, a big opportunity for energy savings involves schemes in which resources are temporarily put into power saving modes, including almost shut-down, at times when they are not needed.

c.3. Chattiness of protocols. For a given protocol, what are the message exchange patterns? does the protocol rely on periodic updates or heartbeat messages? Could such message patterns result in preventing links or nodes from going to sleep (absent other communications), and in such a case, would an alternative pattern be feasible?

c.4. Exploiting burstiness versus smoothening of traffic. Is it feasible to design the protocol to transmit with a smoother traffic pattern with lower traffic volumes that are sent continuously, as opposed to a way that traffic is bulked up and then sent in one fell swoop?

c.5. Rapid discovery and convergence. Does the protocol involve the exchange of state and information about other systems? In that case, how can the protocol be designed in such that any such information can be discovered quickly and protocol synchronization reconverged efficiently? Does the protocol design support stateful schemes that might accelerate this? In cases where there is a possibility of nodes going to sleep, the associated overhead of going offline and coming back online should be minimized. By shortening the time interval needed to go offline and come back online, it might be possible to enter sleep mode in situations where it would otherwise not be feasible.

c.6. Encoding schemes. How much computational effort goes into encoding and decoding? Assess the tradeoff between encoding efficiency and computational effort, which directs into carbon for cycles to perform coding operations.

d. Carbon Awareness:

d.1. Consider Carbon Intensity (CI) / Emission Factor (EF) as an attribute. For example, CI is used to optimize for lower-carbon sources of electrical energy (e.g., using renewables.) Prioritizing electricity use when carbon intensity is low is a target, and, for that, this attribute needs to be accessed or advertised.

d.2. Consider embodied emissions (i.e., embedded carbon) with any new product. For example, a new generation of networking device might significantly improve energy efficiency, and a replacement migration would include the embedded emissions (of producing and transporting the new product as well as disposing of the old one), and hence there’s a break-even point (BEP).

e. Beyond Carbon:
Characterize and note full-spectrum environmental impacts, beyond GHG emissions, and into water usage, raw materials usage, circularity in supply chain, repurpose, reuse, and recycle, etc.

e.1. Resource Awareness and Reporting. Beyond greenhouse gas emissions, protocols should consider enabling awareness of other environmental resources such as water and raw materials. For example, data centers may vary significantly in their water usage for cooling, depending on location, infrastructure, and workload. Protocols can support sustainability by exposing or integrating with telemetry systems that report such metrics. This allows higher-layer systems and orchestration frameworks to make deployment decisions that are sensitive to environmental constraints, such as avoiding water-intensive infrastructure during drought conditions or favoring resource-efficient sites for long-running tasks. Furthermore, protocols can provide policy hooks or signaling interfaces that allow operators to incorporate environmental metrics beyond carbon, into routing, load balancing, and service placement decisions. While the protocols themselves may not directly control hardware or facility resource consumption, they can facilitate the collection and application of such insights in sustainability-aware operations.

e.2. Lifecycle Impact and Circularity. Sustainability also requires a full-lifecycle perspective, considering how protocol design may influence the longevity, reuse, and recyclability of devices and systems. Protocols that prioritize backward compatibility, modularity, and support for older hardware can extend the operational lifespan of network infrastructure, reducing the frequency of hardware refreshes and thereby limiting e-waste. In contrast, designs that require frequent upgrades or discard older technologies prematurely may contribute to unsustainable hardware churn. Protocols can also enable lifecycle tracking through telemetry that helps estimate remaining useful life or suitability for repurposing. By accommodating long-lived devices, especially those in constrained or remote environments, protocols can promote the principles of a circular economy where systems are designed to be reused, repaired, and recycled rather than discarded. Such considerations are particularly important as the scale of Internet-connected devices continues to grow, bringing with it a corresponding increase in material and environmental impact.

4. Conclusion

The pre-eminent message in this document is to elevate the need and sense of urgency of including sustainability considerations in our protocol and system design, and to provide editors with a sustainability lexicon, definitions, and priorities to carry out that task. As an added benefit, by including sustainability considerations, it will be possible to optimize for not only performance parameters but also sustainability ones, through respective trade-offs in our protocols and systems.

We also envision that on top of minimizing the environmental impact of our technologies and helping consumers identify and reduce the environmental impact of their use, we can also make a positive impact on other systems. E.g., use our technologies to choose greener and more efficient sources of power, control HVAC systems efficiently, etc.

4.1. Call to Action

The intention of this document is multifaceted: establish definitions and a lexicon for sustainability, characterize environmental implications of internetworking technologies, and provide specific guidelines for designers and implementers.

Making these objectives actionable involves:

1. Familiarize yourself with the environmental sustainability terms,

2. understand the environmental sustainability implications to protocol and architecture, and

3. consider, qualify, quantify, and explain the specific guidelines in Section 3 as you develop protocols, extensions, and architectures.

5. IANA Considerations

This document has no IANA actions.

6. Security Considerations

Sustainable practices offer many environmental, economic, and social benefits, and security is a route to sustainability rather than a hurdle to clear. However, incorporating sustainability into network protocols and systems introduces new dimensions of trust. Many sustainability-related decisions may rely on external or distributed data sources, such as carbon intensity feeds, energy consumption telemetry, or environmental metrics shared between operators or facilities. It is important to consider the authenticity, integrity, and provenance of this data, especially when such information is used to trigger automated changes in network behavior.

Protocols and systems should therefore support mechanisms to verify the origin and integrity of sustainability data received from external parties. For example, carbon intensity signals could be signed or fetched over authenticated and encrypted channels. Data from managed network elements (e.g., smart power supplies, cooling systems) should be exposed through secure interfaces with appropriate access control and auditability. Where distributed coordination is involved, such as in multi-domain sustainability-aware routing, there is risk of misinformation, either accidental or malicious, impacting global optimization decisions.

Moreover, sustainability-related telemetry may reveal information about network usage patterns, equipment lifecycle stages, or infrastructure sourcing. Care must be taken to ensure that such disclosures do not leak sensitive operational, competitive, or geographical data. Implementations should consider privacy-preserving techniques, such as aggregation, obfuscation, or differential privacy, especially in shared or public reporting contexts.

Security in the sustainability context is not only about protecting the network from external threats, but also about ensuring trustworthy, private, and verifiable environmental data exchange. Without appropriate security, sustainability efforts may be undermined by unreliable data, misreporting, or abuse.

7. Acknowledgements

This document is created greatly leveraging ideas and text from [I-D.cparsk-eimpact-sustainability-considerations], and consequently acknowledges all the many contributions that improved it.

8. Informative References

[I-D.cparsk-eimpact-sustainability-considerations]
Pignataro, C., Rezaki, A., Krishnan, S., ElBakoury, H., and A. Clemm, "Sustainability Considerations for Internetworking", Work in Progress, Internet-Draft, draft-cparsk-eimpact-sustainability-considerations-07, 24 January 2024, <https://datatracker.ietf.org/doc/html/draft-cparsk-eimpact-sustainability-considerations-07>.

[I-D.pignataro-green-enviro-sust-terminology]
Pignataro, C., Rezaki, A., ElBakoury, H., and S. Prabhu, "Environmental Sustainability Terminology and Concepts", Work in Progress, Internet-Draft, draft-pignataro-green-enviro-sust-terminology-02, 12 May 2025, <https://datatracker.ietf.org/doc/html/draft-pignataro-green-enviro-sust-terminology-02>.

Authors’ Addresses

Carlos Pignataro (editor)
Blue Fern Consulting
United States of America
Email: cpignata@gmail.com, carlos@bluefern.consulting

Ali Rezaki
Nokia
Germany
Email: ali.rezaki@nokia.com

Jari Arkko
Ericsson
Email: jari.arkko@ericsson.com

Alexander Clemm
Futurewei
2220 Central Expressway
Santa Clara, CA 95050
United States of America

Email: ludwig@clemm.org

Hesham ElBakoury
Independent Consultant
United States of America
Email: helbakoury@gmail.com

Shailesh Prabhu
Nokia
India
Email: shailesh.prabhu@nokia.com