SPRING Y. Liu
Internet-Draft China Mobile
Intended status: Standards Track C. Lin
Expires: 16 August 2026 New H3C Technologies
R. Chen
ZTE Corporation
J. Li
China Mobile
L. M. Contreras
Telefonica
12 February 2026

Computing Energy Consumption Path in Segment Routing Networks
draft-liu-spring-sr-policy-energy-efficiency-04

Abstract

This document elaborates on the method for calculating energy consumption paths in Segment Routing (SR) networks, aiming to evaluate and optimize traffic-related metrics including energy consumption and carbon emissions on network paths. It covers the procedures for data collection, path computation and issuance, and also specifies the implementation considerations for the data plane in both Multiprotocol Label Switching Segment Routing (MPLS SR) and IPv6 Segment Routing (SRv6) networks.

Status of This Memo

Copyright Notice

Table of Contents

1. Introduction 2
1.1. Requirements Language 3
1.2. Terminology 3
2. Background 4
3. Energy consumption parameters 5
4. Mechanism 6
4.1. Energy Consumption Collection 7
4.2. Path Calculation Based on Energy Consumption 7
4.3. Issuance of Path 7
5. Use Case 8
5.1. Network Path Carbon Emission Assessment 8
6. IANA Considerations 9
7. Security Considerations 9
Acknowledgments 9
References 9
Normative References 9
Informative References 10
Contributors 11
Authors' Addresses 11

1. Introduction

The importance of energy consumption in modern networks is becoming increasingly evident. In addition to techniques such as device sleep modes and dynamic shutdowns, network technologies can also be leveraged to steer traffic toward more energy-efficient devices and paths, thereby reducing the energy consumption of network communications.

[I-D.petra-path-energy-api-02] The PETRA API defines a standardized network energy query interface that allows queries to be sent to the network to retrieve traffic-related energy consumption and environmental-derived metrics for a specified network path. These metrics are computed by the network infrastructure elements dynamically involved in the path. The API only specifies a unified query interaction protocol and does not define the actual computation logic for these metrics.

[I-D.belmq-green-framework-10] mentions an API that enables external systems— such as upper-layer energy management systems, carbon accounting platforms, and operational dashboards— to query and retrieve energy consumption, energy efficiency metrics, and associated metadata for devices or networks. The PETRA API can be used to evaluate traffic-related energy consumption and carbon emissions for any source-to-destination node pair.

[I-D.ietf-green-terminology-00] specifies the metrics applicable to energy consumption assessment and provides a reference for the terminology and parameters used in energy-efficient routing. Among these, the Energy Efficiency Ratio (EER) is a key metric for evaluating the energy conversion efficiency of networks, devices, or components. It is fundamentally defined as the ratio of useful output to energy input in an energy conversion process, and can be used to assess energy consumption or carbon emissions.

[RFC9252] defines the fundamental architecture and operational principles of Segment Routing (SR) and describes the SR network programming model, which enables flexible network path control through the definition of Segment Identifiers (SIDs). This document focuses on path computation based on energy consumption information and utilizes SR to implement energy-aware path control.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119] (Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997) and [RFC8174] (Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017).

1.2. Terminology

Energy Efficiency/Energy Efficiency Ratio (EER): The energy efficiency is expressed as the ratio between the useful output and input of an energy conversion process of a network, device, or component[I-D.ietf-green- terminology-00].

This ratio (i.e., Energy Efficiency Ratio, EER) is the throughput forwarded by 1 watt (e.g., [I-D.cprjgf-bmwg-powerbench]).

2. Background

In the modern digital era, network energy consumption has become a critical focus, driven by the growing demand for sustainable practices and the need to reduce operational costs. Networks consume substantial energy, leading to carbon emissions and environmental degradation. Optimizing energy usage helps reduce their carbon footprint and supports global efforts to combat climate change. Energy is a major operational expense for network operators, and improving efficiency directly lowers electricity costs, especially in large-scale networks, resulting in significant financial savings. As network traffic grows exponentially, energy-efficient designs ensure sustainable scalability without proportional increases in energy consumption, which is essential for supporting future technologies such as 5G, IoT, and cloud computing.

The source routing characteristics of SR make it a flexible, scalable, and efficient networking technology. By simplifying network control, enabling explicit path definition, and ensuring compatibility with existing technologies, SR meets the demands of modern networks for traffic engineering, fault recovery, and scalability while reducing complexity and overhead. Additionally, SR networks support network slicing, allowing the creation of independent paths for different service types.

SR networks can be utilized for energy-efficient path optimization in large-scale networks and seamlessly integrate with existing IPv4/IPv6 infrastructures. By collecting energy consumption data from each node and link, SR enables the planning of energy-efficient paths based on routing policies, thereby achieving the goal of reducing overall network energy consumption.

The motivations for addressing energy consumption in SR networks include, but are not limited to:

1. Reducing energy consumption in network communications by selecting energy-efficient paths and leveraging energy-related information associated with SR paths and policies.

2. Allowing the source node or controller/PCE to use energy consumption metrics as constraints and optimization criteria for path computation, thereby optimizing the routing of network communications.

3. SR networks enable deterministic evaluation of energy consumption and carbon emissions across different paths from source to destination. Due to variations in the geographical locations and construction timelines of Core Network Rooms housing forwarding

devices, there are significant differences in device energy efficiency levels and the proportion of renewable (green) electricity used. Leveraging the capabilities of SR networks, it becomes possible to directly compare and assess the energy cost and carbon footprint of alternative forwarding paths.

3. Energy consumption parameters

Energy consumption parameters include EER, green energy usage ratio, carbon emission factor, etc.

1. Energy Efficiency

The energy efficiency metric EER is expressed in megabits per watt (Mbit/W), representing the actual forwarding throughput achieved per watt of power consumed. A higher value indicates better device energy efficiency. This metric is typically derived from laboratory testing and is distributed in the network as a static value.

For more details on the EER metric, please refer to [I-D.ietf-green-terminology-00].

2. Renewable electricity usage ratio & carbon emission factor

For carbon emission estimation of traffic traversing multi-hop, multi-site paths with varying renewable energy usage ratios across different facilities, a per-segment accounting method SHOULD be employed. For each segment corresponding to a facility along the traffic path, carbon emissions associated with fossil fuel-based electricity MUST be calculated by deducting the portion covered by renewable energy. The carbon emission for a single segment is computed as:

$$C_n = E_n \times F_n \times (1 - R_n)$$

where:

- C_n is the carbon emission of segment n (t CO_2e),
- E_n is the electricity consumption allocated to the traffic on segment n (kWh),
- F_n is the grid average carbon emission factor for the region where segment n is located (t CO_2e/kWh),
- R_n is the renewable energy ratio consumed at the facility of segment n.

The grid average carbon emission factor Fn indicates the carbon intensity of the local power grid. A higher value of Fn implies a higher share of fossil fuel-based electricity, a lower share of renewable energy, and a higher environmental cost associated with power consumption.

The grid carbon emission factor Fn is obtained from official regional grid emission databases, and updated periodically (e.g., annually). The renewable energy ratio Rn is provided per site/facility by the operator’s energy management system or carbon management platform, based on actual renewable energy consumption and credible energy attribute certificates. The network controller does not generate these parameters but retrieves them via northbound interfaces or local configuration.

4. Mechanism

The proposed energy consumption and carbon emission aware path computation framework for SR networks is described as follows:

A centralized controller collects EER parameters from all nodes in the SR domain, and retrieves the renewable energy ratio and carbon emission factor per node from the energy management system and other related platforms.

When a path query is triggered via an external API (e.g., PETRA API), the controller calculates the end-to-end energy consumption and carbon emissions for candidate paths according to the source, destination, and traffic volume. After the optimal path is selected by the API caller, the controller deploys the selected path as an SR Policy to the head-end node.

```
             carbon emission factor
 +-------------------+                 |     API(PETRA API)-Energy Consumption Informatio
n Query
 |Carbon Management |----------|       |
 +-------------------+        \|/      |
                             +--------\|/-------+
                    +--------|Network Controller| Energy Consumption and Carbon Emissions
 Calculation
                    |        +--------/|\-------+
                    |                  |
               SR-Policy        EER Collection
                    |                  |
                +-\|/-+   +------------|-----------+   +-----+
      Handling  |Head |---|    Segment Routing     |---|End  |
      behaviors |Point|   |    Network Domain      |   |Point|
                |     |   |  PE ----- P ------ PE  |   |     |
                +-----+   +------------------------+   +-----+
```

Figure 1: Framework of Computing Energy Consumption path in SR network

4.1. Energy Consumption Collection

Energy Efficiency Ratio (EER) is distributed and collected within the SR network domain through IGP protocol extensions. In cross-domain scenarios, it can be advertised and collected using BGP protocol extensions via BGP-LS (BGP Link-State) extensions.

The collection of energy consumption information between the SR network domain and the network controller adopts standardized methods, such as YANG, NETCONF, and SNMP.

The green power usage ratio and carbon emission factor are obtained by the controller from the carbon management platform.

4.2. Path Calculation Based on Energy Consumption

The network controller selects network paths based on the collected energy consumption information and performs path computation according to a specified policy. First, it calculates N candidate paths using traditional metrics such as bandwidth, delay, and packet loss rate. Then, it evaluates the energy consumption and carbon emissions for each of these paths. Finally, the controller returns the computed results—including both energy and carbon metrics—to the upper-layer application via an API.

It is important to emphasize that carbon emission assessment is critical, as the total power consumption of a path—derived from traffic volume and device energy efficiency ratio (EER)—may not accurately reflect its true environmental impact. For example, suppose the controller receives an API request specifying a source address, destination address, and traffic volume, and computes two candidate paths: Path A has a higher total power consumption than Path B. However, because the data centers or nodes along Path A use a significantly higher proportion of renewable (green) electricity, the resulting carbon emissions—obtained by converting the electricity consumed into CO2 equivalents using location- and time-specific emission factors—are substantially lower for Path A. In this case, despite its higher power draw, Path A represents the environmentally preferable option with a lower overall carbon footprint.

4.3. Issuance of Path

The network controller distributes path to the head end. This distribution can be performed using standard mechanisms such as YANG, BGP or PCEP. The head end then conducts network forwarding based on the distributed SR-Policy. When using YANG, BGP and PCEP, necessary expansions for the energy consumption metric should be made.

5. Use Case

5.1. Network Path Carbon Emission Assessment

```
                 carbon emission factor
    +------------------+                  |     API Query
    |Carbon Management |----------|       |
    +------------------+         \|/      |
                                +--------\|/-------+
                       +--------|Network Controller|
                       |        +------------------+
                       |
                       |
                       |            EER:100 Mbits/W
                    +-\|/-+     +---------P1-------+    +-----+
                    |     |  100|                  |100 |     |
                    |Head |--- PE1                PE2---|End  |
                    |Point|     |    200 Mbits/W   |    |Point|
                    +-----+     +---------P2-------+    +-----+
```

Figure 2: Use Bit0 For Out-of-order Measurement

As shown in the figure above, there are two paths from the head node to the tail node: PE1 -> P1 -> PE2 and PE1 -> P2 -> PE2.

Among them, PE1, PE2, and P1 have the same energy efficiency parameter of 100 Mbits/W, with a green power usage ratio of 50%. Device P2 has an energy efficiency ratio (EER) of 200 Mbits/W and a green power usage ratio of 10%.

At this time, an upper-layer application queries the optional paths from the head node to the tail node, as well as their power consumption and carbon emission costs, via an API.

The calculation process is as follows:

1. After the router devices distribute the parameters via IGP, they synchronize the energy efficiency ratio parameter EER to the network controller through BGP-LS (since EER is a static parameter, it does not need to be flooded repeatedly).

2. The controller obtains the local power grid carbon emission factor Fn of each node and the green power usage ratio Rn of the core network equipment room where the node is located from the carbon management platform.

3. The controller parses the source address, destination address, and traffic volume from the parameters input via the API. Assume the traffic volume is 2000 Mbits.

4. The controller calculates the optional paths:

   * Path 1: PE1 -> P1 -> PE2

   * Path 2: PE1 -> P2 -> PE2

5. The controller calculates the energy consumption and carbon emission level for each segment of the optional paths. In this example, the emission levels of Path 1 and Path 2 differ due to P1 and P2:

   * P1 has an energy efficiency ratio of 100 Mbits/W, so the power consumption for 2000 Mbits traffic is 0.02 kW.The corresponding carbon emission is: Cn = 0.02 × Fn × (1 − 0.5) = 0.01Fn

   * P2 has an energy efficiency ratio of 200 Mbits/W, so the power consumption for 2000 Mbits traffic is 0.01 kW.The corresponding carbon emission is: Cn = 0.01 × Fn × (1 − 0.1) = 0.009Fn

It can be seen from the above that even though P2 has better energy efficiency at the device level, Path 1 has lower carbon emissions due to its higher green power usage ratio.

6. IANA Considerations

The Flow Monitor Option Type should be assigned in IANA.

7. Security Considerations

TBD.

Acknowledgments

The authors would like to thank the following for their valuable contributions of this document: TBD

References

Normative References

[I-D.cprjgf-bmwg-powerbench]
Pignataro, C., Jacob, R., Fioccola, G., and Q. Wu, "Characterization and Benchmarking Methodology for Power in Networking Devices", Work in Progress, Internet-Draft, draft-cprjgf-bmwg-powerbench-05, 7 July 2025, <https://datatracker.ietf.org/doc/html/draft-cprjgf-bmwg-powerbench-05>.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/rfc/rfc2119>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/rfc/rfc8174>.

[RFC9252] Dawra, G., Ed., Talaulikar, K., Ed., Raszuk, R., Decraene, B., Zhuang, S., and J. Rabadan, "BGP Overlay Services Based on Segment Routing over IPv6 (SRv6)", RFC 9252, DOI 10.17487/RFC9252, July 2022, <https://www.rfc-editor.org/rfc/rfc9252>.

Informative References

[I-D.belmq-green-framework-10]
Claise, B., Contreras, L. M., Lindblad, J., Palmero, M. P., Stephan, E., and Q. Wu, "Framework for Energy Efficiency Management", Work in Progress, Internet-Draft, draft-belmq-green-framework-10, 8 February 2026, <https://datatracker.ietf.org/doc/html/draft-belmq-green-framework-10>.

[I-D.ietf-green-terminology-00]
Chen, G., Boucadair, M., Wu, Q., Contreras, L. M., and M. P. Palmero, "Terminology for Energy Efficiency Network Management", Work in Progress, Internet-Draft, draft-ietf-green-terminology-00, 18 November 2025, <https://datatracker.ietf.org/doc/html/draft-ietf-green-terminology-00>.

[I-D.petra-path-energy-api-02]
Rodriguez-Natal, A., Contreras, L. M., Muniz, A., Palmero, M. P., Munoz, F., and J. Lindblad, "Path Energy Traffic Ratio API (PETRA)", Work in Progress, Internet-Draft, draft-petra-path-energy-api-02, 8 July 2024, <https://datatracker.ietf.org/doc/html/draft-petra-path-energy-api-02>.

Contributors

Shujun Hu
China Mobile
Email: lijinming@chinamobile.com

Authors’ Addresses

Yisong Liu
China Mobile
Email: liuyisong@chinamobile.com

Changwang Lin
New H3C Technologies
Email: linchangwang.04414@h3c.com

Ran Chen
ZTE Corporation
Email: xiao.min2@zte.com.cn

Jinming Li
China Mobile
Email: lijinming@chinamobile.com

Luis M. Contreras
Telefonica
Email: luismiguel.contrerasmurillo@telefonica.com