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Sustainability holistic API for Path Energy Evaluation (SHAPE)

draft-amalj-sustain-shape-00

Abstract

This document describes an API to query a network regarding its Energy Traffic Ratio and other sustainability-related metrics for a given network path.

About This Document

This note is to be removed before publishing as an RFC.

The latest revision of this draft can be found at https://galledohm.github.io/draft-amalj-sustain-shape/draft-amalj-sustain-shape.html. Status information for this document may be found at https://datatracker.ietf.org/doc/draft-amalj-sustain-shape/.

Discussion of this document takes place on the Proposed Sustainability and the Internet Proposed Research Group Research Group mailing list (mailto:sustain@irtf.org), which is archived at https://mailarchive.ietf.org/arch/browse/sustain/. Subscribe at https://www.ietf.org/mailman/listinfo/sustain/.

Source for this draft and an issue tracker can be found at https://github.com/galledohm/draft-amalj-sustain-shape.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

Sustainability is becoming one of the major societal goals for the next decade, and networks are one of the major consumers of energy nowadays. Sustainability of network services is thus one of the forefronts of innovation and action from network service stakeholders, involving manufacturers, operators and customers. In this line, there is a shared goal of achieving better energy and carbon awareness.

As with any other network metric, the energy traffic ratio could be collected from the underlying network infrastructure. However, there is not a common or single definition of energy and sustainability metrics towards network consumers so that they can be uniformly reported, particularly in heterogeneous network scenarios. This document introduces an API to query networks about the Energy Traffic Ratio.

Beyond simple efficiency indicators such as watts per gigabit, network stakeholders are increasingly interested in richer sustainability information, such as carbon intensity, energy mix, power usage effectiveness (PUE), idle energy draw, transmission losses, and cooling overheads (e.g., Cooling Energy Ratio). In addition, operational and temporal aspects matter: the ability of a path to spend time in low-power states (Sleep-mode Availability), the variability of carbon intensity over time (Temporal Carbon Variability), and the stability of reported sustainability behavior (e.g., Sustainability Stability Index).

Finally, sustainability data is increasingly used for automated decision-making and assurance (e.g., in green SLAs), which introduces a need for indicators of data quality and robustness. Metrics such as variance of energy consumption (VEC), anomaly detection signals (e.g., Anomaly Factor), and a trustworthiness score of data sources (TDS) help distinguish persistent characteristics from transient conditions and support more reliable sustainability reporting and policy enforcement.

2. Conventions and Definitions

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 BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Sustainability holistic API for Path Energy Evaluation (SHAPE)

This document describes an API to query a network about several sustainability-related metrics for a given path. SHAPE extends PETRA as defined in "draft-petra-path-energy-api-02" (IETF GREEN WG) with additional sustainability metrics. It takes as input the source and destination of a path along with the traffic throughput between and returns energy information related to the traffic on the path. This is energy computed by the infrastructure that is dynamically part of the traffic path. The API is agnostic to the actual hops and underlying infrastructure that enables a path, which might change transparently to the API. This document only describes the API; the computation of the energy information to return is out of the scope of this document.

The API can return a variety of energy-related parameters to provide a complete view of path sustainability. These include base efficiency and footprint indicators (e.g., watts per gigabit and carbon intensity), energy mix and renewable energy contributions, and overhead and operational characteristics (e.g., transmission losses, idle energy draw, cooling overheads, and the availability of low-power states such as sleep modes).

In addition to point-in-time values, the API can expose temporal and assurance-oriented information, such as the variability of carbon intensity over a defined observation window, stability indices for sustainability behavior (e.g., Sustainability Stability Index), statistical measures of energy variability, anomaly signals, and indicators of confidence in the underlying data sources. Such metrics can help consumers distinguish persistent characteristics from transient fluctuations.

Furthermore, the SHAPE’s energy parameters complement ongoing work on green service intents [I-D.irtf-nmrg-ibn-usecases], enabling customers to express sustainability objectives such as energy consumption thresholds, renewable energy usage, and carbon intensity limits. SHAPE provides the underlying energy measurement interface necessary for providers to fulfill, assure, and report on these green intents. Moreover, by exposing detailed energy and carbon-related parameters, SHAPE can allow intent translation components to map green service objectives into network resource allocation and path selection decisions.

3.1. Energy Information

This API allows to return a number of energy attributes associated with the path and the traffic. Currently the parameters that could be returned as energy information as part of the query are:

* *Watts per Gigabit:* (Inherited from PETRA) How many Watts are consumed per Gigabit of traffic traversing the path.

* *Carbon Intensity:* (Inherited from PETRA) How much carbon emissions are generated as a consequence of the energy consumed.

* *Energy Mix (%):* Percentage of energy used in the path that comes from different energy sources (e.g., solar, wind, biomass, nuclear, fossil fuel).

* *Greenness Degree (%):* The aggregated percentage of energy consumed on the path that comes from renewable sources. Useful to rank and select paths based on renewable energy usage.

* *Sustainability Score (01):* Composite metric combining greenness degree and energy efficiency (Watts per Gigabit), calculated as (Greenness/100) × 1/(1 + Watts per Gigabit). Higher values indicate more sustainable, efficient paths.

* *Power Usage Effectiveness (PUE):* The ratio of total facility power consumption to the power consumption of networking/IT equipment.

* *Transmission Loss (%):* The percentage of energy lost along the path due to transmission inefficiencies.

* *Idle Energy Draw (Watts):* The amount of energy consumed by the path infrastructure when idle or under negligible load.

* *Temporal Carbon Variability (TCV) (gCO2/kWh over period):* Quantifies how much the carbon intensity of the electricity powering the network path fluctuates over a defined time window (e.g., 15 minutes, 1 hour, 24 hours). It reflects the stability or volatility of the renewable/fossil mix affecting the path during that period. A low TCV indicates predictable carbon characteristics; a high TCV suggests inconsistent or rapidly changing energy sources.

* *Sleep-mode Availability (%):* Measures the percentage of time during which network devices or segments along a path support and can enter low-power or idle energy-saving modes. It can also reflect real usage of these modes depending on the operator’s instrumentation (when supported or/and instrumented).

* *Sustainability Stability Index (SSI) (01):* Quantifies the stability over time of a sustainability metric (i.e., carbon intensity or greenness degree), it is particularly relevant for gSLAs, where predictable sustainability performance matters as much as absolute values. Values close to 1 indicate highly stable behavior.

* *Trustworthiness Score of Data Sources (TDS) (01):* characterizes how reliable the API’s sustainability-related data is, based on provenance, measurement quality, freshness, and cross-source consistency. Higher values indicate stronger confidence in the reported data.

* *Variance of Energy Consumption (VEC) (W^2):* VEC measures how much the energy use of the path fluctuates during an observation window. It helps detect energy instability, noisy equipment, or poorly tuned power-management algorithms. High VEC indicates unstable or erratic energy usage; low VEC indicates consistent energy behavior.

* *Anomaly Factor (AF) (z-factor):* Identifies whether the energy usage of a path at a given moment deviates significantly from its historical baseline or expected statistical behavior, normalized by standard deviation. AF < 1 indicates normal behavior, AF around 2 indicates elevated deviation, and AF > 3 indicates an anomaly (classic 3-sigma rule).

* *Cooling Energy Ratio (CER) (%):* Quantifies the share of total energy consumed by a path or segment that is attributable to cooling rather than networking/IT workload. It parallels PUE but is per-path or per-segment, not facility-wide. Higher values indicate higher cooling overhead relative to useful forwarding energy.

These metrics are OPTIONAL, and an implementation MAY support a subset depending on available measurement capabilities.

3.2. Recursive Usage

The API is envisioned in such a way that could be used recursively. That means, subpaths could report their energy consumption using SHAPE and such energy consumption could be aggregated and reported for the overall path also using SHAPE.

Similarly, this API could be (recursively) used to provide energy information according to the definition of Service Models in an SDN context as described in [RFC8309]. In that case, using Figure 3 in [RFC8309] as reference, SHAPE could be used between the Controller(s) and the Network Orchestrator(s), between the Network Orchestrator(s) and the Service Orchestrator, and between the Service Orchestrator and the Customer(s).

While considering recursive usage, the aspect of double-counting shall also be taken into consideration. Double counting refers to the fact of counting more than once the same energy consumed. Organizations using SHAPE in a recursive manner need to take appropriate measures to ensure no double-counting occurs across recursive calls to the API.

```
                                                    Customer
                               ------------------   Service  ----------
                              |                  |  Model   |          |
   SHAPE as                   |     Service      |<-------->| Customer |
   Customer Service           |   Orchestrator   |    (a)   |          |
   related API                |                  |           ----------
                               ------------------
                                  .          .
   ##########################    .            .        (b)   -----------
                                . (b)          .      ......|Application|
                               .                .     :     |  BSS/OSS  |
   SHAPE as                   .                  .    :      -----------
   Service related API       .  Service Delivery  .   :
                            .       Model          .  :
                    ------------------    ------------------
                   |                  |  |                  |
   #############   |     Network      |  |     Network      |
                   |   Orchestrator   |  |   Orchestrator   |
                   |                  |  |                  |
                   .------------------    ------------------.
   SHAPE as               .         :                       :        .
   Network API   .         : Network Configuration :         .
               .            :        Model          :         .
         ------------     ------------     ------------    ------------
        |            |   |            |   |            |  |            |
   ###  | Controller |   | Controller |   | Controller |  | Controller |
        |            |   |            |   |            |  |            |
         ------------     ------------     ------------    ------------
            :              .       .                 :            :
            :             .         .      Device    :            :
            :            .           . Configuration :            :
            :            .           .     Model     :            :
        ---------     ---------   ---------     ---------      ---------
       | Network |   | Network | | Network |   | Network |    | Network |
       | Element |   | Element | | Element |   | Element |    | Element |
        ---------     ---------   ---------     ---------      ---------
```

4. YANG Module

SHAPE is specified as an augmentation to the PETRA YANG module defined in [I-D.petra-green-api]. This section provides an example YANG module, as per the YANG specification [RFC7950], that imports PETRA and augments it with additional inputs and metrics.

4.1. Module Structure

```
module: irtf-shape
  +--imports ietf-petra

  augment /petra:energy/petra:query/petra:input:
    +---w measurement-interval?    uint32
    +---w recursive?               boolean

  augment /petra:energy/petra:query/petra:output/petra:result/petra:success:
    +--ro shape-metrics
       +--ro energy-mix*                         -> list of sources and percentages
       +--ro greenness-degree?                   decimal64
       +--ro sustainability-score?               decimal64
       +--ro pue?                                decimal64
       +--ro transmission-loss?                  decimal64
       +--ro idle-watts?                         decimal64
       +--ro temporal-carbon-variability?        decimal64
       +--ro sleep-mode-availability?            decimal64
       +--ro sustainability-stability-index?     decimal64
       +--ro trustworthiness-score?              decimal64
       +--ro variance-energy-consumption?        decimal64
       +--ro anomaly-factor?                     decimal64
       +--ro cooling-energy-ratio?               decimal64
```

4.2. Module Definition

```
module irtf-shape {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:irtf-shape";
  prefix shape;

  import ietf-petra {
    prefix petra;
  }

  organization
    "IRTF SUSTAIN Research Group";
  contact
    "RG Web:   <https://datatracker.ietf.org/rg/sustain/about/>
     RG List:  <sustain@irtf.org>";
```

```
     description
       "Initial YANG module for SHAPE API, v1.0.0

       SHAPE extends the PETRA YANG module ('draft-petra-path-energy-api')
       with additional optional sustainability-related metrics and, where
       needed, additional input parameters to qualify observation windows.

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       authors of the code. All rights reserved.

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       (https://trustee.ietf.org/license-info).

       This version of this YANG module is part of RFC XXXX
       (https://www.rfc-editor.org/info/rfcXXXX); see the RFC itself
       for full legal notices.

       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 BCP 14 (RFC 2119)
       (RFC 8174) when, and only when, they appear in all
       capitals, as shown here.
       ";

   /*
       If you have an implementation of this YANG module, you could
       access it like something this over RESTCONF:

       $ curl --location --request POST \
       'https://localhost:8008/restconf/operations/petra:energy/query' \
       --header 'Content-Type: application/yang-data+json' \
       --user 'admin:admin' \
       --data-raw '{
         "input" : {
           "src-ip": "10.10.10.10",
           "dst-ip": "10.20.20.20",
           "throughput": 40,

           "measurement-interval": 900,
           "recursive": false
         }
       }'
```

```
       And if all goes well, you might receive (besides all the
       HTTP headers) a reply body with something like this:

       {
         "output": {
           "success": {
             "watts-per-gigabit": 191.855,
             "carbon-intensity": 108,
             "shape-metrics": {
               "energy-mix": [
                 { "source": "solar", "percentage": 35.00 },
                 { "source": "wind",  "percentage": 25.00 },
                 { "source": "gas",   "percentage": 40.00 }
               ],
               "greenness-degree": 60.00,
               "sustainability-score": 0.312,
               "pue": 1.20,
               "transmission-loss": 3.50,
               "idle-watts": 12.500,
               "temporal-carbon-variability": 14.250,
               "sleep-mode-availability": 20.00,
               "sustainability-stability-index": 0.880,
               "trustworthiness-score": 0.950,
               "variance-energy-consumption": 1.750,
               "anomaly-factor": 0.420,
               "cooling-energy-ratio": 15.00
             }
           }
         }
       }
   */

     revision 2026-02-26 {
       description
         "Initial SHAPE augmentation of PETRA, adding additional
          sustainability metrics (including temporal/stability and
          trustworthiness indicators).";
       reference
         "RFC XXXX: ...";
     }

     // ===== Groupings =====

     grouping shape-metrics-g {
       description
         "Additional sustainability metrics defined by SHAPE that extend
          the base PETRA query output.";
```

```
       list energy-mix {
         key "source";
         description
           "Percentage contribution of each energy source to the total energy used on the
 path.";
         leaf source {
           type enumeration {
             enum solar;
             enum wind;
             enum hydro;
             enum nuclear;
             enum coal;
             enum gas;
             enum biomass;
             enum other;
           }
           description
             "Type of energy source.";
         }
         leaf percentage {
           type decimal64 {
             fraction-digits 2;
             range "0..100";
           }
           units "%";
           description
             "Percentage of path energy from this source.";
         }
       }

       leaf greenness-degree {
         type decimal64 {
           fraction-digits 2;
           range "0..100";
         }
         units "%";
         description
           "Aggregated percentage of energy from renewable sources.";
       }

       leaf sustainability-score {
         type decimal64 {
           fraction-digits 3;
           range "0..1";
         }
         description
           "Composite metric combining greenness degree and efficiency.
            Suggested formula: (Greenness/100) × 1/(1 + Watts per Gigabit).";
       }
```

```
       leaf pue {
         type decimal64 {
           fraction-digits 2;
           range "1..max";
         }
         description
           "Power Usage Effectiveness: ratio of total facility energy to IT/networking en
ergy.";
       }

       leaf transmission-loss {
         type decimal64 {
           fraction-digits 2;
           range "0..100";
         }
         units "%";
         description
           "Energy lost in transmission as percentage of total energy input.";
       }

       leaf idle-watts {
         type decimal64 {
           fraction-digits 3;
           range "0..max";
         }
         units "W";
         description
           "Energy consumed by the path infrastructure when idle.";
       }

       leaf temporal-carbon-variability {
         type decimal64 {
           fraction-digits 3;
           range "0..max";
         }
         units "gCO2e/kWh";
         description
           "Quantifies how much the carbon intensity powering the path fluctuates over
            an observation window (e.g., 15 minutes, 1 hour, 24 hours).";
       }

       leaf sleep-mode-availability {
         type decimal64 {
           fraction-digits 2;
           range "0..100";
         }
         units "%";
         description
           "Percentage of time during which devices or segments on the path can enter
```

```
            low-power or idle energy-saving modes (when supported and instrumented).";
       }

       leaf sustainability-stability-index {
         type decimal64 {
           fraction-digits 3;
           range "0..1";
         }
         description
           "Index (0..1) capturing the stability over time of a sustainability metric
            (e.g., carbon intensity or greenness degree).";
       }

       leaf trustworthiness-score {
         type decimal64 {
           fraction-digits 3;
           range "0..1";
         }
         description
           "Composite score (0..1) reflecting reliability of reported sustainability data
,
            e.g., based on provenance, quality, freshness, and cross-source consistency."
;
       }

       leaf variance-energy-consumption {
         type decimal64 {
           fraction-digits 3;
           range "0..max";
         }
         units "W^2";
         description
           "Variance of energy consumption over an observation window.";
       }

       leaf anomaly-factor {
         type decimal64 { fraction-digits 3; }
         units "z-score";
         description
           "Deviation of current energy consumption from a historical mean, normalized
            by standard deviation (z-factor).";
       }

       leaf cooling-energy-ratio {
         type decimal64 {
           fraction-digits 2;
           range "0..100";
         }
         units "%";
         description
```

```
            "Ratio between cooling energy and IT/network energy for a path or segment.";
        }
      }

      // ===== Augmentations =====

      augment "/petra:energy/petra:query/petra:input" {
        description
          "Additional optional input parameters for SHAPE that qualify the
           observation window and, when supported, recursive collection.";

        leaf measurement-interval {
          type uint32 {
            range "1..max";
          }
          units "seconds";
          description
            "Observation window used to compute time-dependent metrics (e.g., variability,
             stability, variance, and anomaly indicators).";
        }

        leaf recursive {
          type boolean;
          default "false";
          description
            "Whether the query should be expanded recursively across multiple administrati
ve
             domains (if supported).";
        }
      }

      augment "/petra:energy/petra:query/petra:output/petra:result" {
        description
          "Additional status/error cases for PETRA query output to support
           scenarios where energy data is unavailable or only partially
           available along the resolved path.";

        case energy-unavailable {
          container energy-unavailable {
            description
              "The path was resolved but energy data is not available
               for one or more segments. No watts-per-gigabit can be
               returned. Corresponds to accuracy-unavailable in the
               GREEN data-source-accuracy hierarchy.";
          }
        }

        case partial-result {
          container partial-result {
```

```
           description
             "Energy data is available for part of the path only.
              The watts-per-gigabit returned covers the measurable
              segments. The data-source-accuracy leaf SHOULD be set
              to reflect the least accurate contributing measurement.";
           uses energy-metrics-g;
         }
       }
     }

     augment "/petra:energy/petra:query/petra:output/petra:result/petra:success" {
       description
         "Add SHAPE sustainability metrics to the successful PETRA query result.";

       container shape-metrics {
         description
           "Collection of additional sustainability metrics defined by SHAPE.";
         uses shape-metrics-g;
       }
     }
   }
```

5. Security Considerations

SHAPE queries and responses can reveal operational and business-sensitive information (e.g., energy efficiency, carbon footprint, facility overheads, and potentially location- or time-correlated behavior). SHAPE API MAY be exposed via management protocols such as NETCONF [RFC6241] and RESTCONF [RFC8040] and, therefore, it inherits their security properties and deployment practices. Implementations MUST consider the following aspects:

* *Secure transport:* Implementations MUST ensure confidentiality and integrity protection for SHAPE exchanges (i.e., by using secure transports mandated by the underlying management protocol). Where RESTCONF is used, HTTPS is REQUIRED by [RFC8040].

* *Authentication and authorization:* SHAPE servers MUST authenticate clients and MUST enforce authorization on a per-request basis. Authorization SHOULD be granular (e.g., via access-control mechanisms such as NACM [RFC8341]) and cover: (i) which path endpoints can be queried, (ii) which metrics can be returned (including SHAPE augmentations), and (iii) which precision/granularity is permitted.

* *Information disclosure controls:* Returned sustainability data (i.e., energy mix, PUE, cooling-energy ratio, or temporal variability) can be used to infer facility characteristics,

topology, utilization patterns, or operational policies. Servers SHOULD support policy controls that reduce disclosure risk (e.g., aggregation, reduced precision, or suppressing specific metrics) for less-privileged clients.

* *Input validation and bounds:* Servers MUST validate all inputs (i.e., including path identifiers, throughput, measurement-interval, and the recursive flag) and enforce reasonable bounds to prevent expensive computations and state growth. In particular, servers SHOULD enforce upper limits on observation-window durations, recursion depth/scope, and the amount of per-request data returned.

* *Denial-of-service resilience:* SHAPE computations may involve multi-device sampling, aggregation, and historical lookups. Servers SHOULD implement DoS mitigations such as rate limiting, per-client quotas, request prioritization, and caching of commonly requested results. If requests are rejected due to overload or policy, servers SHOULD return explicit errors rather than silently ignoring requests.

* *Multi-domain and recursive operation:* When the query is expanded recursively across administrative domains, each domain MUST enforce its own local policy and MUST NOT assume that ustream requests are safe. Implementations SHOULD ensure that recursive expansion does not leak credentials, does not bypass local authorization, and does not create amplification (e.g., fan-out storms). Responses obtained from external domains SHOULD be treated as untrusted inputs.

* *Integrity of measurement chain:* SHAPE metrics can be used for automated decisions (e.g., policy enforcement or gSLAs). Implementations SHOULD protect the integrity of the measurement pipeline (collection, aggregation, and publication) and SHOULD provide operational mechanisms such as audit logs and provenance tracking to help detect tampering or misconfiguration.

* *Privacy:* Sustainability metrics may correlate with customer traffic patterns or reveal information about customer locations and activity. Implementations SHOULD minimize retention of per-customer/per-flow data and SHOULD protect logs and telemetry derived from SHAPE requests.

6. IANA Considerations

This document has no IANA actions.

7. References

7.1. Normative References

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Appendix A. Use Cases

This section describes some use-cases where this specification might be useful.

A.1. SD-WAN

Software-Defined Wide-Area Networks (SD-WAN) have become a common way for enterprises to provide cost-effective connectivity across their different geographically distributed sites. Typically, SD-WAN deployments operate as an overlay network that is established on top of an existing underlay connectivity network. One aspect to consider is that in many SD-WAN production deployments the operator of the overlay network and the operator of the underlay network are different organizations.

This poses an additional challenge when trying to derive sustainability metrics. Even if the underlay network is instrumented to collect energy data, this data is opaque to the operator of the overlay network which has no access to underlay information. While operators of underlay networks offer certain general network metrics to overlay operators, no interface has been defined to allow the overlay operator to query the underlay network for energy information.

In this context, the SHAPE specification presented in this document enables the operator of the SD-WAN network to coordinate with the underlay operator to capture sustainability data. This in turns opens further use-cases, from observability and reporting to potentially overlay policies based on underlay energy data, further enabling an overall more sustainable operation of the network.

In addition to energy considerations in SD-WAN deployments, SHAPE can also be leveraged for broader energy-aware service routing. In this context, network controllers and service orchestrators— such as SD-WAN controllers, transport SDN controllers, 5G slice orchestrators, or multi-domain service orchestrators— can use SHAPE metrics not only to balance latency, throughput, or load, but also to optimize path selection according to sustainability objectives. For example, paths with the lowest carbon intensity or the highest share of renewable energy in their energy mix could be preferred, enabling service differentiation where “green paths” are explicitly prioritized. This brings a paradigm where routing decisions are jointly driven by network performance and environmental impact.

A.2. Multilayer Energy Management

The concept of multilayer L3-L1 collection involves integrating data from different network layers to provide a comprehensive view of network operations. The use case of multilayer involves collecting and correlating data from Layer 3 (network layer) down to Layer 1 (physical layer). This multilayer approach allows for better network performance, optimization, and troubleshooting by providing end-to-end visibility.

Leveraging SHAPE API for multilayer L3-L1 collection use case enhances energy management by providing comprehensive visibility, enabling optimization, and supporting proactive management. This makes SHAPE a useful tool for more accurate, efficient and effective energy management in modern networks.

A.3. SLA Negotiation for Green Services

Another use case for SHAPE could be the negotiation of green Service Level Agreements (gSLAs) between operators and enterprise customers. By exposing SHAPE-derived metrics such as renewable energy percentage, carbon intensity, or sustainability scores, providers can offer differentiated SLAs that explicitly include environmental targets. This enables customers to select network services not only based on performance guarantees, but also on their environmental footprint, for example requesting that at least 60% of traffic be carried over renewable-powered infrastructure. Such gSLAs empower customers to align their digital services with corporate sustainability goals and reporting requirements, while operators can use SHAPE as the trusted source of verifiable energy data.

gSLAs can be negotiated using customer-expressed green intents that specify objectives such as maximum energy consumption, minimum energy efficiency, carbon emission limits, and renewable energy usage [I-D.irtf-nmrg-ibn-usecases]. SHAPE’s metrics, including watts per gigabit, carbon intensity, and energy mix, provide essential measurements to translate these intents into network configurations and to monitor compliance during service operation. The lifecycle of green intents, encompassing fulfillment and assurance phases [RFC9315], can be supported by SHAPE through its capability to deliver real-time energy metrics for translation into network policies and subsequent monitoring and validation.

Appendix B. Requirements for Energy Efficiency Management

The document Framework for Energy Efficiency Management [I-D.belmq-green-framework] describes a framework that comprises a controller element. In that document, the tasks of the controller are defined as "collection, compute and aggregate". In the context of that framework, the controller could also expose SHAPE to offer path-related energy information. The figure below updates the one present in [I-D.belmq-green-framework] to add an additional interface (interface ’g’) to the controller to represent the Path Traffic Ratio API.

```
   +--------------------------------------------------------------------+
   |                                                                    |
   |                  (3) Network Domain Level                          |
   |                                                                    |
   +--------------------------------------------------------------------+

   (a)             (b)             (c)
   Inventory       Monitor      +- DataSheets/DataBase
   Of identity     Energy       |  and/or via API
   and Capability  Efficiency   |  Metadata and other
         ^              ^       | device/component/network
         |              |       | related information:                  (g)
         |              |       |                                      SHAPE
         |              |       |  .Power/Energy related metrics         API
         |              |       |  .information                           ^
         |              |       |  .origin of Energy Mix                  |
         |              |       |  .carbon aware based on location        |
         |              |       |                                         |
         |              |       v                                         |
   +--------------------------------------------------------------------+ |
   |                                                                    | |
   |       (2) controller (collection, compute and aggregate?)         +-+
   |                                                                    |
   +--------------------------------------------------------------------+
                   ^                      ^                      ^ |
         (d)        |     (e)              |   (f)                  | |
         Inventory  |     Monitor power    |   Control              | |
         Capability |     Proportion       |   (Energy saving       | |
                    |     Energy efficiency|   Functionality        | |
                    |     ratio, power     |   Localized mgmt/      | |
                    |     consumption,     |   network wide mgmt) | |
                    |     etc)             |                      | |
                    |                      |                      | v
   +--------------------------------------------------------------------+
   |                                                                    |
   |                       (1) Device/Component                         |
   |                                                                    |
   | +---------+  +-----------+  +----------------+  +----------------+ |
   | | (I)     |  | (II)      |  | (III)          |  | (IV)           | |
   | |         |  |           |  | Legacy         |  | ’Attached’(PoE | |
   | | Device  |  | Component |  | Device         |  | end Point)     | |
   | |         |  |           |  |                |  |                | |
   | +---------+  +-----------+  +----------------+  +----------------+ |
   +--------------------------------------------------------------------+
```

Figure 1: SHAPE Integration in Energy Management Framework

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