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SUSTAINABLE AND SLA-SATISFYING TRAFFIC ENGINEERING

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ABSTRACT

A network controller allows clients of the data center to make decisions on how to incorporate green services into their data center usage. A green-aware Service Level Agreement (SLA) map provides insight into the sustainability factors for each node that is used to perform a service for the client. The green-aware SLA map is determined according to an Environment Conscious (EC) metric that quantifies the environmental and sustainability impacts of performing a service at a data center.

DETAILED DESCRIPTION

State of the art datacenters may have many features and properties that have varying degrees of environmental impact, such as liquid cooling, renewable power, battery-stored power shifting, among other features. These features provide an opportunity to classify services running in these data centers as greener in comparison to legacy data centers Additionally, the proposal outlined here quantifies the environmental impact of a service network system, which may be a logical system in the order of tens of thousands of nodes (e.g., switches, routers, servers, etc.), allowing an enterprise customer to be SLA compliant and meet sustainability goals.

This proposal is described from the perspective of a network controller perspective that enables clients to decide on how to select among the environmentally conscious services that contribute toward minimizing the global environmental impact. For instance, a client may have a net-zero initiative that requires all carbon sources (e.g., through power generation, construction, transportation, etc.) to be balanced by carbon sinks (e.g., renewable energy, carbon capture and sequestration, etc.). The network controller additionally interfaces with various traditional SLA monitoring tools as required to ensure that all the decisions based on environmental effects are satisfying the underlying SLA requirement for the service.

The network controller creates a green-aware SLA map, where each node of the map represents a single network element in the network. The network element may be a physical or virtual computing device (e.g., a physical switch/router, a virtual switch/router), or a service component (e.g., a microservice, a set of microservices, or an element from the microservice architecture).

Each of these nodes within the SLA map is represented by a varied number of vectors specific to the class of the node, which describe that specific node. A network device node may have vectors that describe the SLA requirements of a network device (e.g., switch uptime, port flap interval, etc.) A microservice architecture connection node may have SLA metric vectors that describe features specific to connection uptime and bandwidth utilization.

Additionally, the network controller defines an environmental metric for each node in the SLA map based on the sustainability information available for the location of the node. For instance, some data centers may be powered, at least in part, using renewable resources such as solar, wind, and/or hydroelectric generation. Services available in these data centers may be considered to be fully or partially powered by green energy. The environmental metric may quantify both the amount of energy that is derived from green sources as well as how environmentally impactful the green energy source is.

As a general overview, this proposal includes a network controller that computes an Environment Conscious (EC) metric for every service and/or device in the network. The EC-metric aggregates information from different environmental design certification programs with traditional SLA metrics to identify the appropriate instance to satisfy a customer’s intent to access network services with consideration for environmental consequences.

In one example, the EC-metric may be computed from a combination of existing environmental information about the service nodes controlled by the network controller. For instance, the EC-metric may be based on a combination of Leadership in Energy and

Environmental Design (LEED) factors for the data center and Energy Star ratings for individual appliances.

The LEED rating system for whole buildings (e.g., data centers) is the leading green and environmental design certification program in the world. The overall LEED rating of a building typically depends on a myriad of individual factors, which may or may not be relevant to an individual customer's usage of resources within a data center. This proposal considers a subset of the LEED factors, as shown in Table 1.

S No	Data type	Max Value
1	Heat Island Reduction	2
2	Enhanced Commissioning	6
3	Optimize Energy Performance	18
4	Advanced Energy Metering	1
5	Grid Harmonization	2
6	Renewable Energy	6
7	Enhanced Refrigerant Management	1

Table 1 – LEED factors for EC-metric

The network controller may gather the values of each of these LEED factors and may be retrieved from a central database for each network location onboarded in the controller. The LEED ratings quantify the environmental impact of each data center in which the network controller has network assets available for customers.

In addition to the LEED factors, which quantify the overall data center operation, the network controller also gathers Energy Star ratings for individual appliances that may be operated by the network controller. In one example, the Energy Star for server v2.0 certification may be based on the Server Efficiency Rating Tool (SERT) that collects data on the server energy efficiency of individual network appliances or groups of network appliances.

The network controller may expand the SERT 2.0 suite results to obtain workload-specific differentiation of the SERT metric for all of the applications available to the network controller. If the network controller expands the SERT metric, then the network controller may normalize the values obtained from the SERT 2.0 suite prior to computing the SERT metric. For instance, the network controller may compute the geometric mean to normalize the SERT values. The full detailed dataset allows the network controller to recompute a combined value of the LEED ratings and the Energy Star ratings for the EC-metric.

To compute the EC-metric the network controller generates an EC-vector to represent each service available from the network controller. As shown in Figure 1 below, the EC-vector combines values from a LEED node and a SERT node. The LEED node summarizes values from the LEED rating (e.g., the Heat Island Reduction rating, the Enhanced Commissioning rating, the Optimize Energy Performance rating, etc.) for the data center where the service is available.

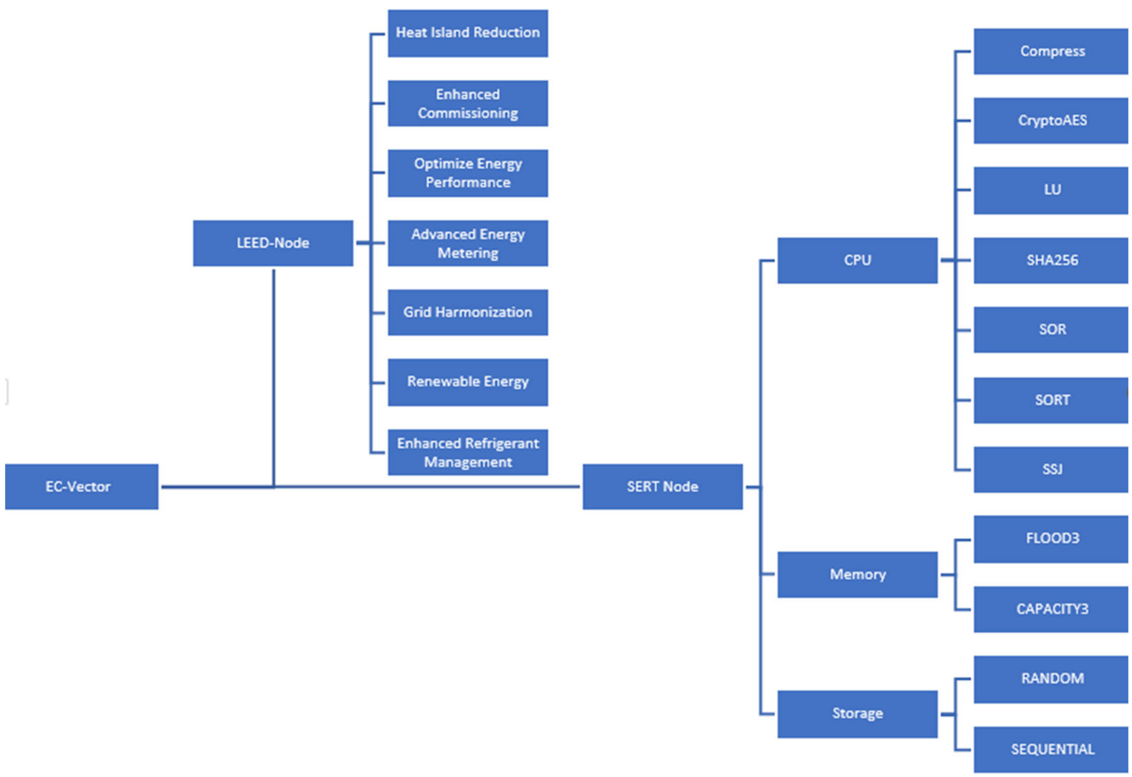

Figure 1 – Environment Conscious Vector

The SERT node summarizes values from the SERT suite v2.0 (e.g., CPU workload efficiency, memory workload efficiency, and storage workload efficiency) for an individual appliance or device supporting the service. Each component of the SERT node may be further subdivided into more specific worklets. For instance, the CPU workload efficiency may include worklets related to CPU efficiency performing different tasks (e.g., compression, cryptography, sorting, etc.).

The combination of the values from the LEED node and the SERT node generates an EC-vector that represents the overall environmental impact of a service. The network controller may determine that a subset of vectors if one or more of the components (e.g., specific LEED factors or SERT worklets) represent a particular service more effectively.

By default, the network controller generates the EC-vector from equal contributions from each node by calculating the geometric mean of each vector component. every vector is going to equally contribute towards the summarized vector. However, a user may direct the network controller to weigh one or more of the vector components if a weighted average represents the characteristics of the service node more accurately. For instance, a user may place a higher value on certain LEED ratings and direct the network controller to increase the weight of those LEED ratings in the calculation of the EC-vector. Alternatively, a user may direct the network controller to exclude certain vectors if those vectors do not contribute significantly to a particular service. For instance, the network controller may adjust the EC-vector for a storage service node by weighting SERT CPU metrics significantly lower than SERT Storage metrics, or by completely disregarding certain SERT worklets (e.g., CPU Server Side Java (SSJ)) that have minimal impact on a storage service.

In one example, the network controller may update an EC-metric any time the server hosting a service node changes. In this proposal, the network controller considers the Environmental, Social, and Governance (ESG) factors of the servers running a particular service, without consideration for whether the intermediary network is ESG compliant. However, the EC-metric may be extended to include every intermediary device from a client to the server hosting the service node for a specific request.

Based on the EC-metric, the network controller enables a user to provide an SLA that enforces the user's emphasis on providing environmentally conscious services. By balancing and redirecting traffic flows towards SLA-compliant servers according to the EC-metric, the network controller ensures that the terms of the SLA are met by service nodes with minimized environmental impact.

A network controller for a network may enable environmentally aware services by generating a green-aware SLA map, as shown in FIG. 2, below. In the green-aware SLA map shown in Figure 2, each node represents a single element in the network. The network element may be a physical switch, a virtual switch, a microservice, a set of microservices, or an element from the microservice architecture, all representing a service which is managed by the network controller.

To generate the map, the network controller may collect an SLA compliance (Health Score) SLA_{HS} and an EC-metric for each of the N nodes in the network. In other words, for every network element that a network controller can use to provide a particular service, the network controller collects data about the capability of each network element and about the environmental impact of operating each network element.

With this data, the network controller may generate the green-aware SLA map as a max-heap binary decision tree, with the key being the EC score. In the example shown in Figure 2, for service S_A, with six nodes, the green-aware SLA map allows the network controller to make traffic steering decisions for each service.

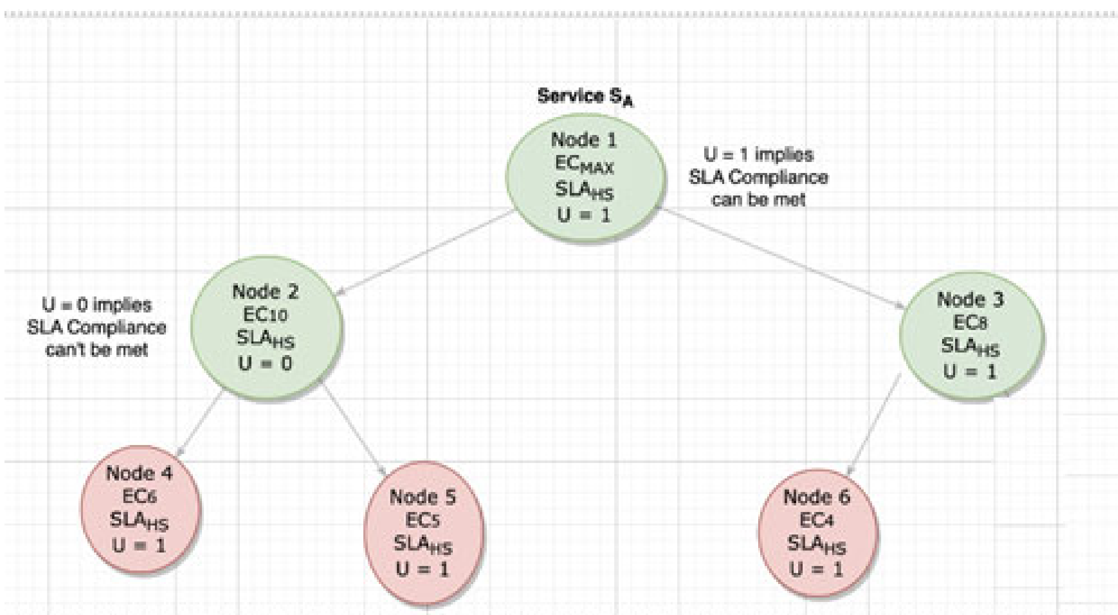

Figure 2 – Green-Aware SLA Map

The max-heap decision tree of Figure 2 enables the network controller to select the node with the highest EC-metric score that can meet the SLA compliance requirements of the service S_A. With a max-heap decision tree keyed on the EC-metric, the root node (i.e., Node 1) has the highest environmental score and is able to meet the SLA compliance requirements. This green-aware SLA map provides the core of an algorithm for environmentally conscious decision making for providing services. The EC-metric is a generic value which may also be extended to other use-cases as appropriate.