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SIMAP: Concept, Requirements, and Use Cases
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Abstract

This document defines the concept of Service & Infrastructure Maps (SIMAP) and identifies a set of SIMAP requirements and use cases. The SIMAP was previously known as Digital Map.

The document intends to be used as a reference for the assessment of the various topology modules to meet SIMAP requirements.

Discussion Venues

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

Discussion of this document takes place on the Network Management Operations Working Group mailing list (nmop@ietf.org), which is archived at <https://mailarchive.ietf.org/arch/browse/nmop/>.

Source for this draft and an issue tracker can be found at <https://github.com/ietf-wg-nmop/draft-ietf-nmop-digital-map-concept>.

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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Table of Contents

1. Introduction	3
2. Terminology	4
3. Sample SIMAP Use Cases	6
3.1. Common Enablers for SIMAP	7
3.1.1. Service -> Resource	7
3.1.2. Resource -> Service	7
3.1.3. Traffic Engineering (TE)	7
3.1.4. Closed Loop	8
3.2. Inventory Queries	8
3.3. Service Placement Feasibility Checks	10
3.4. Intent/Service Assurance	10
3.5. Service E2E and Per-link KPIs	11
3.6. Network Capacity Planning	11
3.7. Network Design	13
3.8. Network Simulation and Network Emulation	14
3.8.1. Types of Network Simulation	14
3.8.2. Goals of Network Simulation	15
3.9. Postmortem Replay	16
3.10. Network Digital Twin (NDT)	17
4. SIMAP Requirements	17
4.1. Operator Requirements	18
4.2. Design Requirements	24
4.3. Architectural Requirements	25
5. Positioning SIMAP in the Context of the IETF Work	26
6. Security Considerations	28
7. IANA Considerations	28
8. References	28
8.1. Normative References	28
8.2. Informative References	28
Appendix A. Related IETF Activities	33

A.1. Network Topology	33
A.2. Topology Abstraction	34
A.3. Core SIMAP Components	34
A.4. Additional SIMAP Components	34
Acknowledgments	35
Contributors	35
Authors' Addresses	35

1. Introduction

This document defines the concept of Service & Infrastructure Maps (SIMAP) and outlines associated requirements and use cases. It does not specify a modeling approach for SIMAP; references to existing models and modeling languages are provided for informational purposes only. While the requirements described herein may require various modeling strategies, the development of such models is outside the scope of this document.

SIMAP is a data model that provides a view of the operator's networks and services, including how it is connected to other models/data (e.g., inventory, observability sources, and operational knowledge). It specifically provides an approach to model multi-layered topology and an appropriate mechanism to navigate amongst layers and correlate between them. This includes layers from physical topology to service topology. This model is applicable to multiple domains (access, core, data center, etc.) and technologies (Optical, IP, etc.).

The SIMAP modelling defines the core topological entities (network, node, link, and termination point) at each layer, their role in the network topology, core topological properties, and topological relationships both inside each layer and between the layers. It also defines how to access other external models from a topology. SIMAP is a topological model that is linked to other functional models and connects them all: configuration, maintenance, assurance (KPIs, status, health, and symptoms), Traffic-Engineering (TE), different behaviors and actions, simulation, emulation, mathematical abstractions, AI algorithms, etc. These other models exist outside of the SIMAP and are not defined during SIMAP modelling.

The SIMAP data consists of virtual instances of network and service topologies at different layers. The SIMAP provides access to this data via standard APIs for both read and write access, typically as a northbound interface from a controller, with query capabilities and links to other data models (e.g., Service Assurance for Intent-based Networking (SAIN) [RFC9417], Service Attachment Points (SAPs) [RFC9408], Inventory [I-D.ietf-ivy-network-inventory-yang], and potentially linking to non-YANG models). The SIMAP also provides write operations with the same set of APIs, not to change a topology

layer on the fly as a northbound interface from the controller, but for offline simulations, before applying the changes to the network via the normal controller operations.

Both real network and offline simulation APIs are similar, stemming from the same data model, to facilitate the comparison of the offline simulated SIMAP with the network one.

2. Terminology

This document makes use of the following terms:

Topology: Topology refers to the network and service topology. A network topology defines how physical or logical nodes, links and termination points are related and arranged. A Service topology defines how service components (e.g., VPN instances, customer interfaces, and customer links) between customer sites are interrelated and arranged.

There are several types of topologies: point-to-point, bus, ring, star, tree, mesh, hybrid, and daisy chain.

Topologies may be unidirectional or bidirectional (bus, some rings).

Multi-layered topology: A multi-layered topology models relationships between different topology layers, where each layer represents a connectivity aspect of the network and services that needs to be configured, controlled and monitored. Each topology layer has a separate lifecycle.

[RFC8345] also refers to this multi-layered topology as topology hierarchy (stack). It also uses layers when describing supporting relations (represent layered network topologies), underlay/overlay, network nodes and layering information. [RFC8345] states that the model can be used for representation of layered network topologies.

[RFC8345] is flexible and can support both the same network topology instance with multiple layers (e.g., Layer 2 and Layer 3) or separate network topology instances with supporting relations between them (e.g., separate Layer 2 and Layer 3). Therefore, multiple topology layers can be grouped into the same network topology instance, if solution requires.

Topology layer: A topology layer represents Topology at a single layer in the multi-layered topology.

The topology layer can also represent what needs to be managed by a specific user or application, for example the IGP layer can be of interest to the operator troubleshooting or optimizing the routing, while the optical layer may be of interest to the user managing the optical network.

Some topology layers may relate closely to OSI layers, like Layer 1 topology for physical topology, Layer 2 for link topology and Layer 3 for IPv4 and IPv6 topologies.

Some topology layers represent the control aspects of Layer 3, like OSPF, IS-IS, or BGP.

The service layer represents the Service view of the connectivity, that can differ for different types of Services and for different providers/solutions.

The top layer represents the application/flow view of Service connectivity.

Service: A service represents network connectivity service provided over a network that enables devices, systems, or networks to communicate and exchange data with each other. It provides the underlying infrastructure and mechanisms necessary for establishing, maintaining, and managing connections between different endpoints. The example services are: L2VPN, L3VPN, EVPN, VPLS, VPWS,

Resource: Defined in [I-D.ietf-nmop-terminology]

Termination Point: Defined in [RFC8345], as follows:

The network-topology module defines a topology graph and components from which it is composed: nodes, edges, and termination points. Nodes (from the "ietf-network" module) represent graph vertices and links represent graph edges. Nodes also contain termination points that anchor the links.

A node has a list of termination points that are used to terminate links. An example of a termination point might be a physical or logical port or, more generally, an interface. Like a node, a termination point can in turn be supported by an underlying termination point, contained in the supporting node of the underlay network.

The document defines the following terms:

Service & Infrastructure Maps (SIMAP): SIMAP is a data model that

provides a view of the operator's networks and services, including how it is connected to other models/data (e.g., inventory, observability sources, and operational knowledge). It specifically provides an approach to model multi-layered topology and an appropriate mechanism to navigate amongst layers and correlate between them. This includes layers from physical topology to service topology. This model is applicable to multiple domains (access, core, data centers, etc.) and technologies (Optical, IP, etc.)

Therefore, SIMAP defines the core topological entities, their role in the network, core topological properties, and relationships both inside each layer and between the layers. It is a basic topological model with references/pointers to other models and connects them all: configuration, maintenance, assurance (KPIs, status, health, symptoms, etc.), traffic engineering, different behaviors, simulation, emulation, mathematical abstractions, AI algorithms, etc.

SIMAP modelling: SIMAP modelling is the set of principles, guidelines, and conventions to model the SIMAP. They cover the network types (layers and sublayers), entity types, entity roles (network, node, termination point, or link), entity properties, relationship types between entities and relationships to other entities.

SIMAP data: SIMAP data consists of instances of network and Service topologies at different layers. This includes instances of networks, nodes, links and termination points, topological relationships between nodes, links and termination points inside a network, relationships between instances belonging to different networks, links to functional data for the instances, including configuration, health, symptoms.

The SIMAP data can be historical, real-time, or future data for 'what-if' scenarios.

3. Sample SIMAP Use Cases

The following subsections provide a non-exhaustive list of SIMAP use cases, with a focus on the related application requirements and its interactions with SIMAP, in order to extract the SIMAP-related requirements (Section 4).

3.1. Common Enablers for SIMAP

This section identifies a set of enablers that are invoked when providing the various business-oriented SIMAP use cases. These enablers are grouped here to avoid duplication.

3.1.1. Service -> Resource

The SIMAP APIs can be invoked to retrieve all Services for selected service types. An application that triggers such a request will be able to retrieve the topology for selected Services via the SIMAP APIs and, from the response, it will be able to navigate via the supporting relationship top-down to the lower layers. In doing so, the application will be able to determine what logical resources are used by a Service. The supporting relations to the lowest layer will help the application to determine what physical resources are used by the Service.

3.1.2. Resource -> Service

An application can navigate from the physical, Layer 2, or Layer 3 topology to the Services that rely upon specific resources. For example, the application will be able to select the resources and by navigating the supporting relationship bottom-up come to the Service and its nodes, termination points and links.

This APIs can be invoked for Service impact analysis, for example.

3.1.3. Traffic Engineering (TE)

Traffic Engineering (TE) [RFC9522] is a network optimization technique designed to enhance network performance and resource utilization by intelligently controlling the flow of data, for example by enabling dynamic path selection based on constraints such as bandwidth availability, latency, and link costs. Its primary goals are to prevent network congestion, balance traffic loads, and ensure efficient use of bandwidth while meeting performance requirements.

The TE use case is a combination of both the capacity planning and the simulation use case. Therefore, there are no specific SIMAP requirements.

3.1.4. Closed Loop

A network closed loop refers to an automated and intelligent system where network operations are continuously monitored, analyzed, and optimized in real time through feedback mechanisms. This self-adjusting cycle ensures that the network dynamically adapts to changes, resolves issues proactively, and maintains optimal performance without manual intervention.

Key Characteristics of a network closed loop:

- * Real-time monitoring: Collects data from network devices, traffic flows, and applications to build a comprehensive view of network health and performance.
- * Automated analysis: Identify anomalies, predict potential failures, or detect security threats, for example leveraging AI and machine learning.
- * Proactive action: Automatically triggers corrective measures, such as reconfiguring devices, isolating compromised endpoints, or rerouting traffic.
- * Continuous optimization: Uses feedback from previous cycles to refine network policies and improve future responses.

The application will be able to retrieve a topology layer and any network/node/termination point/link instances from the controller via the SIMAP APIs and from the response it will be able to map the traffic analysis to the entities (typically links and router) for automated analysis. The corrective measures would be applied, either directly to the network by managing the SIMAP entities (network/node/termination point/link instances) or by first validating the corrective measure in an offline simulation (see the simulation and traffic engineering use cases).

3.2. Inventory Queries

A network inventory refers to a comprehensive record or database that tracks and documents all the network components and devices within an organization's IT infrastructure.

Key elements typically found in a network inventory include:

- * Hardware details: Descriptions of physical devices such as routers (including their internal components such as cards, power supply units, pluggables), switches, servers, network cables, including model numbers, serial numbers, and

manufacturer information. This information will facilitate locating additional details of the hardware in the manufacturer systems and the correlation with the purchase catalog of the company.

- * Software and firmware: Versions of operating systems, network management tools, and firmware running on network devices. Note that a network device can have components with their own software and firmware.
- * Licensing information: For any licensed software or devices, the network inventory will track license numbers, expiry dates, and compliance.

A network inventory lifecycle refers to the stages a network device or component goes through from its introduction to the network until its removal or replacement. It encompasses everything from acquisition and deployment to maintenance, upgrade, and eventually decommissioning. Managing the network inventory lifecycle efficiently is crucial for maintaining a secure, functional, and cost-effective network.

A well-maintained network inventory helps organizations with network management, troubleshooting, asset tracking, security, and ensuring compliance with regulations. It also helps in scaling the network, planning upgrades, and responding to issues quickly. In order to facilitate the planning and troubleshooting processes it is necessary to be able to navigate from network inventory to network topology and Services.

The application will be able to retrieve physical topology from the controller via the SIMAP APIs and from the response it will be able to retrieve the physical inventory of individual devices and cables and the customer information, if applicable.

The application may request either one or multiple topology layers via the SIMAP APIs and from the response it will be able to retrieve both physical and logical inventory.

For access network providers the ability to have linkage in the SIMAP of the complete network (active + passive) is essential as it provides many advantages for optimized customer Service, reduced Mean Time To Repair (MTTR), and lower operational costs through truck roll reduction. For example, operators may use custom-tags that are readily available for a customer-facing device, then query the inventory based on that tag to correlate it with the inventory and then map it to the network/service topology. The mapping and correlation can then be used for triggering appropriate Service checks.

The IVY working group is a good source of information for inventory information.

3.3. Service Placement Feasibility Checks

Service placement feasibility checks refer to the process of evaluating whether a specific Service can be deployed and operated effectively in a given network. This includes accessing the various factors to ensure that the service will function as intended (e.g., based on traffic performance requirements) without causing network disruptions or inefficiencies and effecting other Services already provisioned on the network.

Some of the factors that need assessing are network capabilities, status, limitations, resource usage and availability. The Service could be simulated during the feasibility checks to identify if there are any potential issues. The load testing could be done to evaluate performance under stress.

The service placement feasibility check application will be able to retrieve the topology at any layer from the controller via the SIMAP APIs and from the response it will be able to navigate to any other data models outside of the core SIMAP topology to retrieve any other information needed, such as resource usage, availability, status, etc.

3.4. Intent/Service Assurance

Network intent and Service assurance work together to ensure that the network aligns with business goals and that the Services provided meet the agreed-upon Service Level Agreements (SLAs).

The Service Assurance for Intent-Based Networking Architecture (SAIN) [RFC9417] approach emphasizes a comprehensive view of components involved in Service delivery, including network devices and functions, to effectively monitor and maintain Service health.

The key objectives of this architecture include:

- * Holistic service monitoring: By considering all elements involved in Service delivery, the architecture enables a thorough assessment of service health.
- * Correlation of Service degradation: It assists in linking Service performance issues to specific network components, facilitating precise identification of faults.
- * Impact assessment: The architecture identifies which Services are affected by the failure or degradation of particular network components, aiding in prioritizing remediation efforts.

When a Service is degraded, the SAIN architecture will highlight where to look in the assurance Service graph, as opposed to going hop by hop to troubleshoot the issue. More precisely, the SAIN architecture will associate a list of symptoms originating from specific SAIN subservices to each Service instance, corresponding to components of the network. These components are good candidates for explaining the source of a Service degradation.

The application will be able to retrieve a topology layer and any network/node/termination point/link instances from the controller via the SIMAP APIs and from the response it will be able to determine the health of each instance by navigating to the SAIN subservices and its symptoms.

3.5. Service E2E and Per-link KPIs

The application will be able to retrieve a topology at any layer from a controller via the SIMAP APIs and from the response it will be able to navigate to and retrieve any KPIs for selected topology entity.

3.6. Network Capacity Planning

Network capacity planning refers to the process of analyzing, predicting, and ensuring that the network has sufficient capacity (e.g., [RFC5136]), resources, and infrastructure to meet current and future demands. It involves evaluating the network's ability to handle increasing (including forecasted) amounts of data, traffic, and users' activity, while maintaining acceptable levels of performance, reliability, and security.

The capacity planning primary goal is to ensure that a network can support business operations, applications, and services without interruptions, delays, or degradation in quality. This requires a thorough understanding of the network's current state, as well as future requirements and growth projections.

Key aspects of network capacity planning include:

- * Traffic analysis: Monitoring and analyzing network traffic patterns to identify trends, peak usage periods, and areas of congestion. For example, by generating a core traffic matrix with IPFIX flow record [RFC7011] or deducting an approximate traffic matrix from the link utilization data.
- * Resource utilization: Evaluating the link utilization throughout the network for the current demand to identify bottlenecks and potential QoS performance issues.
- * Growth forecasting: Predicting future network growth based on business expansion, new applications, or changes in users' behavior.
- * What-if scenarios: Creating models to assess the network behavior under different scenarios, such as increased traffic, failure conditions (link, router or Shared Risk Resource Group), and new application deployments (such as a new Content Delivery Network source, a new peering point, a new data center...).
- * Upgrade planning: Identifying areas where upgrades or additions are needed to ensure that the network can minimize the effect of node/link failures, mitigate QoS problems, or simply to support growing demands.
- * Cost-benefit analysis: Evaluating the costs and benefits of upgrading or adding new resources to determine the most cost-effective solutions.

By implementing a robust capacity planning process, organizations can:

- * Ensure better network reliability: Minimize downtime and ensure that the network is always available when needed.
- * Improve performance: Optimize network resources to support business-critical applications and Services.
- * Optimize costs: Avoid unnecessary over-provisioning by making informed decisions based on data-driven insights.

- * Support business growth: Scale the network to meet increasing demands and support business expansion.

The application will be able to retrieve a topology layer and any network/node/termination point/link instances from the controller via the SIMAP APIs and from the response it will be able to map the traffic analysis to the entities (typically links and router), evaluate their current utilization, evaluate which elements to add to the network based on the growth forecasting, and finally perform the 'what-if' failure analysis by simulating the removal of link(s) and/or router(s) while evaluating the network performance.

3.7. Network Design

Network design involves defining both the logical structure, such as access, aggregation, and core layers, and the physical layout, including devices and links.

It serves as a blueprint, detailing how these elements interconnect to deliver the intended network behavior and functionality. The application will retrieve a candidate network topology as the initial design, which can then undergo further analysis (e.g., perform traffic flow simulations to identify bottlenecks and redundancy checks to ensure resilience) before being transformed into actionable intent and, eventually, deployment actions.

Throughout the network's lifecycle, the design rules embedded within a topology can be continuously validated. For example, a link rule might specify that a connection between core and aggregation layers must have its source(s) and destination(s) located within the same data center. Another example is to declare that a specific link type should only exist between Core <-> Aggregation layer with certain constraints on port optic speed, type (LR vs SR for instance), etc.

The application can (via SIMAP API):

- * Write the proposed network interconnect (topology + rules), this is a new potential network interconnect. One network (in case of small network) or interconnect of multiple networks (bigger networks).
- * Write the intended network interconnect (topology + rules), this is the intent of the network topology that cannot be retrieved from the real network (e.g. our L2 topology interconnect intent, or L3 topology interconnect intent). One network (in case of small network) or interconnect of multiple networks (bigger networks).

- * Retrieve the proposed network interconnect (topology + rules)
 - Use case can be for purpose of traffic simulation, testing behavior under failures. Network simulation use case is described in Section 3.8.
 - Use case can be for purpose of comparing different proposed network interconnects.
 - Use case can be to build a simulated environment using this design. Network simulation use case is described in Section 3.8.
- * Retrieve the intended network interconnect (topology + rules)
- * At any point in time, compare the discovered topology with intended one
 - Potentially validating discovered device configurations with intended ones assuming SIMAP has the external reference to configuration from topology.

3.8. Network Simulation and Network Emulation

Network simulation is a process used to analyse the behaviour of networks via software. It allows network engineers and researchers to assess how the network protocols work under different conditions, such as different topologies, traffic loads, network failures, or the introduction of new devices. Network emulation, on the other hand, replicates the behavior of a real-world network, allowing for more realistic analysis compared to network simulation. While network simulation focuses on modeling and approximating network behavior, network emulation involves creating a real-time, functional network environment whose protocols behave exactly like a real network. Ideally, network emulation uses the same software images as the real network, but it could also be performed (with less accuracy) using generic software.

3.8.1. Types of Network Simulation

There are several types of network simulations, each designed to address specific needs and use cases. Below are the main categories of network simulation:

1. Discrete event simulation: This is the most common type of

network simulation. It models a series of events that occur at specific points in time. Each event triggers a change in the state of a network component (e.g., a link is down, a card fails, or a packet arrives).

2. Continuous simulation: In contrast to discrete event simulation, continuous simulation models systems where variables change continuously over time. Network parameters like bandwidth, congestion, and throughput can be treated as continuous functions.

The main use case is to model certain aspects of network performance that evolve continuously, such as link speeds or delay distributions in links that are impacted by environmental conditions (such as microwave or satellite links).

3. Monte Carlo simulation: This type of simulation uses statistical methods to model and analyze networks under uncertain or variable conditions. Monte Carlo simulations generate a large number of random samples to predict the performance of a network across multiple scenarios. It is used for probabilistic analysis, risk assessment, and performance evaluation under uncertain conditions.

3.8.2. Goals of Network Simulation

The simulations can be also classified depending on the goal of the simulation.

3.8.2.1. Network Protocol Analysis

This type of simulation focuses on simulating specific networking protocols (IS-IS, OSPF, BGP, SR) to understand how they perform under different conditions. It models the protocol operations and interactions among devices in the network. For example, simulation can be used to assess the impact of changing a link metric. Moreover, specific features of the networking protocol can be tested. For example, how fast-reroute performs in a given network topology.

3.8.2.2. Traffic Simulation

This simulation focuses on modelling traffic flow across the network, including packet generation, flow control, routing, and congestion. It aims to evaluate traffic's impact on network performance.

The main use is to model the impact of different types of traffic (e.g., voice, video, mobile data, web browsing) and understand how they affect the network's bandwidth and congestion levels. It can be used to identify bottlenecks and assist the capacity planning process.

3.8.2.3. Simulation of Different Topologies Under Normal and Failure Scenarios

This type of simulation focuses on the structure and layout of the network itself. It simulates different network topologies and their impact on the network's performance. It can be used, together with the traffic simulation, to evaluate the most efficient topology for a network under normal conditions and considering factors like fault tolerance.

3.9. Postmortem Replay

For the postmortem replay use case, the application will use the SIMAP APIs for the purpose of analysis of network Service property evolution based on recorded changes. A collection of relevant timestamped network events, such as routing updates, configuration changes, link status modifications, traffic metrics evolution, and Service characteristics, is being made accessible from and/or within a SIMAP to support investigation and automated processing. Using a structured format, the stored data can be replayed in sequence, allowing network operators to examine historical network behavior, diagnose issues, and assess the impact of such events on Service assurance.

The mechanism supports correlation with external data sources to facilitate comprehensive post-mortem analysis. Beyond centralizing and correlating such various sources of information, the SIMAP can provide simulation of the network behaviour to assist investigations.

In essence, this use case builds upon a collection of other SIMAP use cases, such as inventory queries, intent/service assurance, Service KPIs, capacity planning, and simulation, to provide a thorough understanding of a network event impacting Service assurance.

Note that this use case may serve as a component of Service Disruption Detection fine tuning as described in [I-D.ietf-nmop-network-anomaly-architecture].

3.10. Network Digital Twin (NDT)

Per [I-D.irtf-nmrg-network-digital-twin-arch], Network Digital Twin (NDT) is a digital representation that is used in the context of Networking and whose physical counterpart is a data network (e.g., provider network or enterprise network). Also, as discussed in Section 9.2 of [I-D.irtf-nmrg-network-digital-twin-arch], network element models and topology models help generate a virtual twin of the network according to the network element configuration, operation data, network topology relationship, link state and other network information. The operation status can be monitored and displayed and the network configuration change and optimization strategy can be pre-verified.

Section 9.4 of [I-D.irtf-nmrg-network-digital-twin-arch] further elaborates on the requirements on various interfaces:

- * Network-facing interfaces are twin interfaces between the real network and its twin entity. They are responsible for the information exchange between a real network and NDT. SIMAP APIs can be invoked within such interfaces.
- * Application-facing interfaces are between the NDT and applications. They are responsible for the information exchange between Network Digital Twin and network applications. SIMAP APIs can be used for feasibility checks (Section 3.3) or emulation (Section 3.8)).

Section 9.4 of [I-D.irtf-nmrg-network-digital-twin-arch] recommends that these interfaces are open and standardized so as to avoid either hardware or software vendor lock and achieve interoperability.

While network emulation (Section 3.8) can be a component within an NDT, the NDT itself is a broader construct that integrates multiple modeling techniques, including emulation, simulation, and analytics, to support intelligent network operations. NDT uses network emulation and includes network emulation use case, but it also interacts with the real network to support intelligent operations, including predictive analytics, intent verification, and full lifecycle management of network and services.

4. SIMAP Requirements

The SIMAP requirements are split into three groups for different target audiences:

- * Operator requirements: These requirements are collected from the

operators. They are functional requirements derived from the operators' use cases. Some of the more specific semantic requirements were identified as [RFC8345] gaps during the Hackathons with operators and added as specific semantic requirements to the operator use cases.

- * Design requirements: These requirements are derived from the operators' requirements. Although there is some duplication, these are focused on summarizing the operators' requirements for the design of the data model and API. These are functional requirements translated into low-level requirements for the model designers. The rationale for adopting this approach is to ensure that the data model is designed according to the operators' requirements and that they could be used for both design and review of the candidate data models.
- * Architecture requirements: Architectural (non-functional) requirements are captured as well, as operators identified performance needs, large scale support, and network discovery. These are not data model requirements, but are requirements either to drive the APIs design itself (e.g., to better optimize performance) or for the network controllers and orchestrators that expose a SIMAP API. Although, they may be common sense requirements not specific to SIMAP API, they are listed here for completeness.

4.1. Operator Requirements

The following are the operators' requirements for the SIMAP. Note that some of these requirements are supported by default by [RFC8345].

REQ-BASIC-MODEL-SUPPORT: Basic model with network, node, link, and termination point entity types.

This means that users of SIMAP must be able to understand a topology model at any layer via these core concepts only, without having to go to the details of the specific augmentations to understand the topology.

REQ-LAYERED-MODEL: Topology layers from physical layer up to Service layer.

SIMAP must provide views for all layers of network topology, from physical network (ideally optical), Layer 2, Layer 3 up to Service and intent views. It must provide flexibility to support both the same network topology instance with multiple layers (e.g., Layer 2 and Layer 3) or separate network topology instances with

supporting relations between them (e.g., separate Layer 2 and Layer 3). Multiple topology layers can be grouped into the same network topology instance, if solution requires.

REQ-VIEWPOINTS: SIMAP should provide different views to different applications. For example, one application may need to see Layer 2 and Layer 3 layers in a single network topology instance, while another application may need to see them as separate network topology instances.

REQ-PASSIVE-TOPO: SIMAP must support capability to model topology of the complete network, including active and passive parts.

For access network providers the ability to have linkage in the SIMAP of the complete network (active + passive) is essential as it provides many advantages for optimized customer Service, reduced MTTR, and lower operational costs through truck roll reduction.

The passive topology must be either implemented in the SIMAP (what cannot be discovered can be added using the write API) or accessible from the SIMAP. Whether the passive topology is included as part of the SIMAP or accessible from the SIMAP is left to the solutions.

REQ-PROG-OPEN-MODEL: Open and programmable SIMAP.

This includes "read" operations to retrieve the view of the network, typically as application-facing interface of Software Defined Networking (SDN) controllers or orchestrators.

It also includes "write" operations, not for the ability to directly change the live SIMAP data (e.g., changing the network or Service parameters), but for offline simulations, also known as what-if scenarios.

Running a "what-if" analysis requires the ability to take snapshots and to switch easily between them.

Note that there is a need to distinguish between a change on the SIMAP for future simulation and a change that reflects the current reality of the network.

REQ-STD-API-BASED: Standard-based SIMAP and APIs, for multi-vendor support.

SIMAP must provide the standard APIs that provide for read/write

and queries. These APIs must also provide the capability to retrieve the links to external data/models.

REQ-COMMON-API: SIMAP and common APIs, for multi domain.

SIMAP and its APIs must be common over different network domains (campus, core, data center, etc.).

This means that clients of the SIMAP APIs must be able to understand the topology model of layers of any domain without having to understand the details of any technologies and domains.

REQ-GRAPH-TRAVERSAL: Topology graph traversal.

SIMAP must be optimized for graph traversal for paths and for graph traversal for the specific use case queries. This means that only providing link nodes and source and sink relationships to termination-points may not be sufficient, we may need to have the direct relationship between the termination points or nodes.

REQ-TOPOLOGY-ABSTRACTION: Navigation across the abstraction levels.

A network (even a single layer network) can be represented in multiple ways providing different abstraction views of the same network. In such a case, it would be beneficial being able to navigate amongst the different levels of abstractions (e.g. to understand which set of nodes in the native topology are actually represented as a single node in an abstract topology being built on top of the native topology). This navigation is different and orthogonal to the multi-layer navigation where we need to report which Layer 2 path is supporting a given Layer 3 node or link. Nevertheless, it would not be the best practice to expose it via different topology APIs and model. Please refer to the Appendix A.2 for some background on the topology abstraction.

SIMAP must provide a mechanism to navigate across the abstraction levels.

REQ-LIVE: Live network topology.

SIMAP must enable retrieval of multi-layered topology of a live network.

Live network is the latest known view of the network

REQ-SNAPSHOT: Network snapshot topology.

SIMAP must enable retrieval of multi-layered topology of different

snapshots

Snapshot is the view of the network at any given point in time

REQ-POTENTIAL: Potential new network topology.

SIMAP must enable both retrieval and write access to the potential new network.

A potential new network is the view at a given point with modifications from the snapshot.

This view may contain either the full topology or just differences from the snapshot.

REQ-INTENDED: Intended network topology.

SIMAP must enable both retrieval and write access to the intended network topology that cannot be discovered from the real network (e.g., intended Layer 2 Topology, intended Layer 3 Topology, and passive topology that cannot be discovered).

REQ-SEMANTIC: Network topology semantics.

SIMAP must provide semantics for layered network topologies and for linking external models/data.

The following requirements are more specific requirements for semantics:

REQ-LAYER-NAVIGATE: SIMAP must provide capability to navigate inside the topology layer and between the topology layers.

REQ-EXTENSIBLE: SIMAP must be extensible with metadata.

REQ-PLUGG: SIMAP must be pluggable. That is,

- * Must connect to other data models for device configuration, inventory, configuration, assurance, etc. The SIMAP does not contain the detailed device configuration, so a mechanism is needed to be able to link it from SIMAP. SIMAP should also be linked to a 'logical configuration inventory'. Several examples of the type of logical information to be linked from SIMAP: inventory of logical interfaces, inventory of ACLs, or inventory of routing policies.

- * Given that not all involved components can be available using YANG, there is a need to connect SIMAP with other modelling mechanisms.

REQ-BIDIR: SIMAP must provide a mechanism to model bidirectional links. While data flows are unidirectional, the bidirectional links are also common in networking. Examples are Ethernet cables, bidirectional SONET rings, socket connection to the server, etc. There is also the requirement for simplified Service layer topology, where a link is modeled as bidirectional in order to be supported by unidirectional links at the lower layer.

REQ-MULTI-POINT: SIMAP must provide a mechanism to model multipoint links. A topology model should be able to model any topology type in a simple and explicit way, including point to multipoint, bus, ring, star, tree, mesh, hybrid and daisy chain. A topology model should also be able to model any link cardinality in a simple and explicit way, including point-to-point, point-to-multipoint, multipoint-to-multipoint or hybrid.

REQ-MULTI-DOMAIN: SIMAP must provide a mechanism to model links between networks. This requirement is about covering connectivity between different networks, sub-networks, or domains.

REQ-SUBNETWORK: SIMAP must provide a mechanism to model network decomposition into sub-networks. The requirement is about modelling hierarchical networks, Autonomous Systems (ASes) with multiple areas, or a network with multiple domains (e.g., access, core, data center).

The network can be partitioned by providing capability to have multiple child network instances as part of a single parent network, with a relation between the parent network and child networks.

REQ-SHARED: SIMAP must provide a mechanism to share nodes, links, and termination points between different networks.

REQ-SUPPORTING: SIMAP must provide a mechanism to model supporting relationships between different types of topological entities (e.g., a termination point is supported by the node). This may be required, e.g., if a termination point is not supported by the underlying a termination point, but by the node (e.g., a loopback does not have physical representation, so it is supported by physical device).

REQ-STATUS: Links and nodes that are down must appear in the

topology. The status of the nodes and links must be either implemented in the SIMAP or accessible from the SIMAP. Whether the status is included as part of the SIMAP or accessible from the SIMAP is left to the solutions.

REQ-DATA-PLANE-FLOW: Provider data plane (Flow) needs to be correlatable to underlay and customer data plane to overlay topology

An SRv6 example:

In a SRv6 enabled network, sourceIPv6Address appears in a IPFIX data-template/data-record for a captured flow on a SRv6 enabled provider interface twice. Once in relation to provider data plane in the underlay, and once as relation to the customer data plane in the overlay.

SIMAP must provide the semantic capability that each sourceIPv6Address can be mapped to the overlay and underlay network topology. Both topologies might not be uniquely addressed, the VPN context (in SRv6 these are the SID's, Section 3 of [RFC8986]) needs to be considered therefore as well.

IPFIX protocol, defined in [RFC7011], is the protocol for the exchange of flow information from an Exporting Process to a Collecting Process. Section 8 of [RFC7011] describes the management of Templates and Option templates at the Exporting and Collecting Processes, and states the following:

If an Information Element is required more than once in a Template, the different occurrences of this Information Element SHOULD follow the logical order of their treatments by the Metering Process. For example, if a selected packet goes through two hash functions, and if the two hash values are sent within a single Template, the first occurrence of the hash value should belong to the first hash function in the Metering Process. For example, when exporting the two source IP addresses of an IPv4-in-IPv4 packet, the first sourceIPv4Address Information Element occurrence should be the IPv4 address of the outer header, while the second occurrence should be the address of the inner header. Collecting Processes MUST properly handle Templates with multiple identical Information Elements.

REQ-CONTROL-PLANE: Underlay control plane routing state needs to be correlatable to underlay L3 topology. Overlay control-plane routing state needs to be correlate-able to overlay L3 network topology.

A BMP/BGP example:

The BMP peer distinguisher (Section 4.2 of [RFC7854]) needs to be correlateable to the VRF of a node and the next-hop attribute of the NLRI in the BMP route-monitoring (Section 4.6 of [RFC7854]) encapsulated message to the underlay network topology while the path attribute of the NLRI in the BMP route-monitoring encapsulated message to the overlay topology.

4.2. Design Requirements

The following are the design requirements for the SIMAP data model:

REQ-TOPO-ONLY: SIMAP should contain only topological information.

SIMAP is not required to contain all models and data required for all the management and use cases. However, it should be designed to support adequate pointers to other functional data and models to ease navigating in the overall system. For example:

- * ACLs and Route Policies are not required to be supported in the SIMAP, they would be linked to the SIMAP.
- * Dynamic paths may, depending on the solution, be either inside or outside of the SIMAP. If outside of SIMAP, dynamic paths could be linked to the SIMAP.

SIMAP should ensure that it is possible to represent the paths/routes and leave the choice of what level of dynamics to represent to the specific solution/application. The model needs to be rich enough to represent any level of dynamics. However, from experience, we suspect it can be the same model for all level of dynamics.

REQ-PROPERTIES: SIMAP entities should mainly contain properties used to identify topological entities at different layers, identify their roles, and topological relationships between them.

SIMAP entities should also provide information required to define semantics for layered network topologies, such as:

- * link directionality,
- * whether the links are multipoint or not and, if so, are whether these links are point-to-multipoint or multipoint-to-multipoint,
- * role of the termination points in the link (source, destination, hub, spoke), and

- * some generic mechanism to add metadata.

REQ-RELATIONSHIPS: SIMAP should contain all topological relationships inside each layer or between the layers (underlay/overlay)

SIMAP should contain links to other models/data to enable generic navigation to other data models in generic way.

The SIMAP relationships should also provide information required to define semantics for layered network topologies, such as providing:

- * underlay and overlay relations between different types of topological entities,
- * additional information that helps with navigation inside a layer and between the layers, for example, easy identification of resources at the physical layer in primary versus backup paths, if the underlay resources are used for load balancing or for backup,
- * capability to model nodes, termination points, and links contained in a network, but also nodes and links shared between networks, and
- * relationships between networks, either for modelling of underlay and overlay or modelling network that contains multiple networks.

REQ-CONDITIONAL: Provide capability for conditional retrieval of parts of SIMAP.

REQ-TEMPO-HISTO: Must support geo-spatial, temporal, and historical data. The temporal and historical can also be supported external to the SIMAP.

4.3. Architectural Requirements

The following are the architectural requirements for the controller implementations that provide SIMAP API, they are the non-functional requirements for the SIMAP APIs and controller implementations:

REQ-SCALES: The SIMAP APIs and controller implementations must be scalable, it must support any provider network, independent of its size.

REQ-PERFORMANCE: The SIMAP APIs and controller implementations must be performant, and have acceptable response-time. Although we are not to define the response time here.

REQ-USABILITY: The SIMAP APIs must be simple and easy to integrate with the client applications, whose developers may not be networking experts.

REQ-DISCOVERY: A network controller must perform the initial and on-demand discovery of a network in order to provide the layered topology via the SIMAP APIs to a client/application.

REQ-SYNCH: The controller must perform the sync with the network in order to provide up to date layered topology via SIMAP APIs to the client/application

REQ-SECURITY: The conventional NACM control access rules [RFC8341] should apply. This includes module control access rules, protocol operation control access rules, data node control access rules, and notification control access rules.

5. Positioning SIMAP in the Context of the IETF Work

[RFC8199] advocates for a consistent classification of YANG modules and introduces two abstraction layers for YANG modules:

- * network element YANG modules
- * network service YANG modules

The IRTF [RFC7426] defines the SDN layers and architecture and proposes the following interfaces:

- * southbound interfaces between the network devices and controllers/managers
- * service interface between controllers/managers and applications

[RFC8309] defines where service model might fit into the SDN Architecture, although the service model does not require or preclude the use of SDN. It shows the following models at different layers of abstraction:

- * device model, between network elements and controllers
- * network model, between controllers and network orchestrators
- * service model, between network orchestrators and service orchestrators
- * customer service model, between service orchestrators and customer

[RFC8453] describes the ACTN architecture in the context of the YANG service models. It shows how ACTN interfaces relate to device model, network model and customer service model.

[RFC8969] describes a framework for Service and network management automation that takes advantage of YANG modelling technologies. This framework is drawn from a network operator perspective irrespective of the origin of a data model. [RFC8969] introduces "network service models" and describes the layering and representation of models within a network operator as follows:

- * device model, between device and controller
- * network model (operator oriented), between controller (that includes network orchestration function) and service orchestrator
- * service model (customer oriented), between service orchestrator and customer, this is network service model

The SIMAP can be used at different layers of abstraction and SIMAP can provide topology at different interfaces. Although the SIMAP and APIs is primarily positioned as northbound multi-layered topology model from (SDN) Controllers, it can also be positioned as follows:

- * In the context of [RFC8199], SIMAP can provide multi-layered topology YANG module as part of both network element and network service YANG modules
- * In the context of [RFC7426], SIMAP can provide multi-layered topology interface as part of both Southbound and Service Interfaces
- * In the context of [RFC8309], SIMAP can provide multi-layered topology model as part of device model, network model, service model and customer service model
- * In the context of [RFC8453], SIMAP can provide multi-layered topology model as part of SBI (southbound interface to network), MPI (interface between multi-domain service coordinator and network controller) and CMI (interface between customer network controller and multi-domain service controller)
- * In the context of [RFC8969], SIMAP can provide multi-layered topology model as part of device model, network model and network service model

6. Security Considerations

As this document covers the SIMAP concepts, requirements, and use cases, there is no specific security considerations other than those discussed in Section 4.3.

Section 8 of [RFC8345] discusses security aspects that will be useful when designing the SIMAP solution.

7. IANA Considerations

This document has no actions for IANA.

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Appendix A. Related IETF Activities

Note: The models cited in this section are provided for illustration purposes. It is out of scope to recommend which models will be used as base to build the SIMAP.

A.1. Network Topology

Interestingly, we could not find any network topology definition in IETF RFCs (not even in [RFC8345]) or Internet-Drafts. However, it is mentioned in multiple documents. As an example, in Overview and Principles of Internet Traffic Engineering [RFC9522], which mentions:

To conduct performance studies and to support planning of existing and future networks, a routing analysis may be performed to determine the paths the routing protocols will choose for various traffic demands, and to ascertain the utilization of network resources as traffic is routed through the network. Routing analysis captures the selection of paths through the network, the assignment of traffic across multiple feasible routes, and the multiplexing of IP traffic over traffic trunks (if such constructs exist) and over the underlying network infrastructure. A model of network topology is necessary to perform routing analysis. A network topology model may be extracted from:

- * Network architecture documents
- * Network designs
- * Information contained in router configuration files
- * Routing databases such as the link state database of an interior gateway protocol (IGP)
- * Routing tables
- * Automated tools that discover and collate network topology information.

Topology information may also be derived from servers that monitor network state, and from servers that perform provisioning functions.

Another example is [RFC8453] that defines native topology, abstract topology, black topology, and grey topology, but all in the context of actual topology and physical topology that are not specifically defined.

A.2. Topology Abstraction

Please refer to the following documents for some background on topology abstractions:

- * [RFC7926] defines topology abstraction.
- * Section 5 of [RFC8453] describes the topology abstraction methods and discusses topology abstraction factors, types, and their context in the ACTN architecture.
- * Section 3.13 of [RFC8795] defines abstract TE topologies.
- * Section 4.1 of [RFC8795] defines native TE topologies.
- * Section 4.4 of [RFC8795] describes how to deal with multiple abstract TE topologies provided by the same provider.
- * Section 1.3 of [I-D.ietf-teas-te-topo-and-tunnel-modeling] gives some background on topology abstraction.

A.3. Core SIMAP Components

The following specifications are relevant to the core functions provided by the SIMAP:

- * IETF network model and network topology model [RFC8345]
- * A YANG grouping for geographic location [RFC9179]
- * IETF modules that augment [RFC8345] for different technologies:
 - A YANG data model for Traffic Engineering (TE) Topologies [RFC8795]
 - A YANG data model for Layer 2 network topologies [RFC8944]
 - A YANG data model for OSFP topology [I-D.ogondio-opsawg-ospf-topology]
 - A YANG data model for IS-IS topology [I-D.ogondio-nmop-isis-topology]

A.4. Additional SIMAP Components

The SIMAP may need to link to the following models, some are already augmenting [RFC8345]:

- * Service Attachment Point (SAP) [RFC9408], augments 'ietf-network' data model [RFC8345] by adding the SAP.
- * SAIN [RFC9417] [RFC9418]
- * Network Inventory Model [I-D.ietf-ivy-network-inventory-yang] focuses on physical and virtual inventory. Logical inventory is currently outside of the scope. It does not augment [RFC8345].
- * [I-D.ietf-ivy-network-inventory-topology] correlates the network inventory with the general topology via RFC8345 augmentations that reference inventory.
- * KPIs: delay, jitter, loss
- * Attachment Circuits (ACs) [I-D.ietf-opsawg-ntw-attachment-circuit] and [I-D.ietf-opsawg-teas-attachment-circuit]
- * Configuration: The L2SM [RFC8466], L3SM [RFC8299], L2NM [RFC9291], and L3NM [RFC9182]
- * Incident Management for Network Services [I-D.ietf-nmop-network-incident-yang]

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