An Architecture for a Network Anomaly Detection Framework

draft-netana-nmop-network-anomaly-architecture-00

Motivation and architecture of a Network Anomaly Detection Framework
and the relationship to other documents describing
network symptom semantics and network incident lifecycle

wanting.du@swisscom.com
pierre.francois@insa-lyon.fr
thomas.graf@swisscom.com
vincenzo.riccobene@huawei-partners.com

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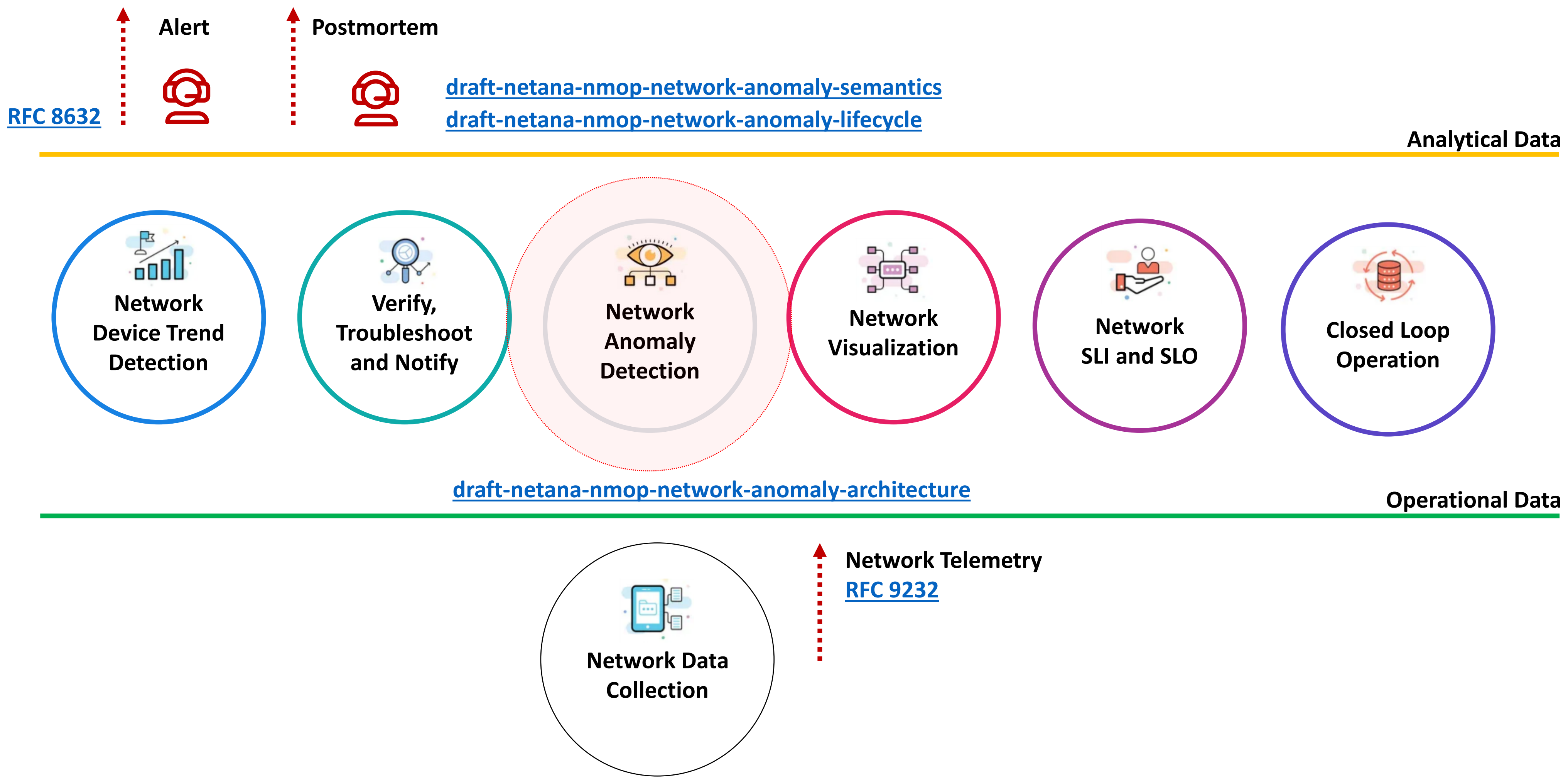
Data Mesh organizes Data in Organizations

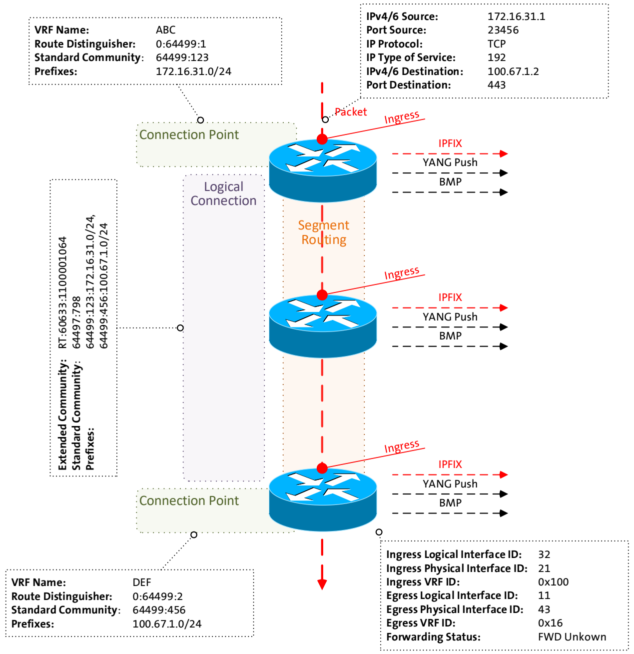
Enables Network Analytics use cases



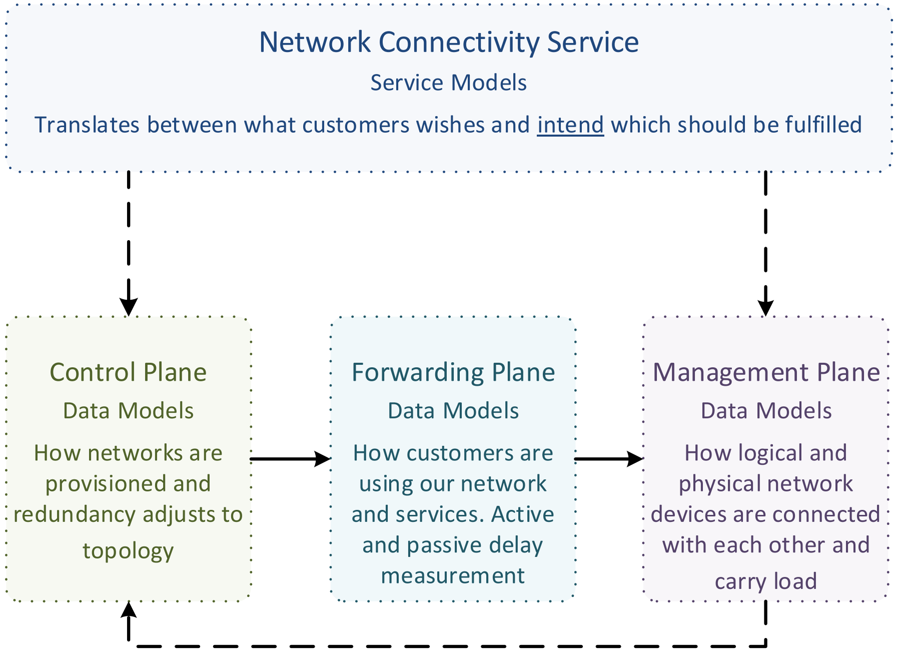
What to monitor

Which operational metrics are collected

« Network operators connect customers in routing tables called Connectivity Services »



« Network Telemetry (RFC 9232) describes how to collect data from all 3 network planes efficiently »



What does Network Anomaly Detection mean

Monitor changes, called outliers, in networks

Network Anomaly Detection

For Connectivity Services, Network Anomaly Detection **constantly monitors and detects any network or device topology change**, along with their associated forwarding consequences for customers as outliers. Notifications are sent to the Network Operation Center before the customer is aware of service disruptions. **It offers operational metrics for in-depth analysis,** allowing to understand in which platform the problem originates and facilitates problem resolution.

Answers

What changed and when, on which connectivity service, and how does it impact the customers?

Focuses

Provides meaningful connectivity service impact information before customer is aware of and support in root-cause analysis.

Data Mesh

Consumes operational real-time Forwarding Plane, Control Plane and Management Plane metrics and produces analytical alerts.

Direction

From connectivity service to network platform.

What our motivation is

Automate learn and improve

From network incidents postmortems we network operators **learn and improve** so does network anomaly detection and supervised and semi-supervised machine learning.

The more network incidents are observed, the more we can improve. With more incidents the **postmortem process needs be automated, let's get organized** first by defining human and machine-readable metadata semantics and annotate operational and analytical data.

Let's get further organized by exchanging standardized labeled network incident data among network operators, vendors and academia to **collaborate on academic research**.

« The community working on Network Anomaly Detection is probably the only group wishing for more network incidents »

Elements of the Architecture

```
        +---------+                     +--------------------+
        |Service  |                     |     Alert and      |
   |--- |Inventory|                     | Problem Management |
   |    |         |                     |       System       |
   |    +---------+                     +--------------------+
   |      |                                     ^     Stream
   |      |                                     |
   |      |        +---------+          +--------------------+
   |      |        | Post-   | Stream   |   Message Broker   |
   |      |        | mortem  | <------- |  with Analytical   |
   |      |        | System  |          |    Network Data    |
   |      |        +---------+          +--------------------+
   |      |             |                       ^     Stream
   |      |             |                       |
   |      |             |               +--------------------+
   |      | Profile     | Fine          | Alert Aggregation  | Store Lab
   |      | and         | Tune          | for Anomaly        | ---------
   |      | Generate    | SDD           | Detection          |
   |      | SDD Config  | Config        +--------------------+
   |      |             |                    ^  ^  ^ Stream
   |      v             v                    |  |  |
   |   +--------------------+           +--------------------+        +-
   |   | Service Disruption| Schedule   | Service Disruption| Replay  |
   |   |     Detection      | --------> |     Detection      |<------  |
   |   |   Configuration    | Detection |                    |         |
   |   +--------------------+           +--------------------+        +-
   |                                      ^ ^ Stream ^ ^ ^
   |                                      | |        | | |
   |                                    +----------+----------+
   |                                    | Network  |  Data    | Store
   |--------------------------------->  |  Model   |  Aggr.   | ---------
                                        |          | Process  | Operation
                                        +----------+----------+
                                             ^  ^  ^ Stream
                                             |  |  |
                                        +--------------------+
                                        |   Message Broker   |
                                        |  with Operational  |
                                        |    Network Data    |
                                        +--------------------+
                                             ^  ^  ^ Stream
Subscribe                       Publish      |  |  |
          +--------------------+        +--------------------+
          | Network Node with  | ------>| Network Telemetry  |
--------> | Network Telemetry  | ------>| Data Collection    |
          |    Subscription    | ------>|                    |
          +--------------------+        +--------------------+
```

- **Service Inventory** contains list of the connectivity services.
- **Service Disruption Detection** processes aggregated network data to decide whether a service is degraded or not.
- **Service Disruption Detection Configuration** defines the set of approaches that need to be applied to perform SDD.
- **Operational Data Collection** manages network telemetry subscriptions and transforms data into message broker.
- **Operational Data Aggregation** produces data upon which detection of a service disruption can be performed.
- **Network Modeling** establishes knowledge of network relationships.
- **Data Profiling** categorizes nondeterministic customer related data.
- **Detection Strategies** for a profile a detection strategy is defined.
- **Machine Learning** is commonly used to detect outliers or anomalies.
- **Storage** some algorithms may relay on historical (aggregated) operational data to detect anomalies.
- **Alerting** consolidates analytical insights and notifies.
- **Postmortem** refines and stores the network anomaly and symptom labels into the Label Store.
- **Replaying** to validate refined anomaly and symptom labels, historical operational data is replayed.

Experiment: Network Anomaly Lifecycle

draft-netana-nmop-network-anomaly-lifecycle

4. Lifecycle of a Network Anomaly

The lifecycle of a network anomaly can be articulated in three phases, structured as a loop: Detection, Validation, Refinement.

```
                         +-------------+
             +--------> | Detection  | ---------+
 Adjustments |           +-------------+         | Symptoms
             |                                   |
             |                                   v
      +------------+                      +------------+
      | Refinement |<-------------------- | Validation |
      +------------+       Incident       +------------+
                         Confirmation
```

Figure 1: Anomaly Detection Refinement Lifecycle

Each of these phases can either be performed by a network expert or an algorithm or complementing each other.

Detection: The Network Anomaly Detection stage is about the continuous monitoring of the network through Network Telemetry [RFC9232] and the identification of symptoms.

Validation: Decides if the detected symptoms are signaling a real incident or if they are to be treated as false positives.

Refinement: Network operator performs detailed postmortem analysis of the network incident, collected Network Telemetry data and detected anomaly with the objective to identify useful adjustments in the Network Telemetry data collection and Anomaly Detection system.

Semantic Metadata Annotation for Network Anomaly Detection

draft-netana-nmop-network-anomaly-semantics

```
module: ietf-network-anomaly-metadata
  +--rw network-anomalies
     +--rw network-anomaly* [id author-name version state]
        +--rw id                yang:uuid
        +--rw description?      string
        +--rw author
        |  +--rw author-name       string
        |  +--rw author-type?      identityref
        |  +--rw algo-version?     uint8
        +--rw version           uint8
        +--rw state             identityref
        +--rw symptoms* [symptom_id]
           +--rw symptom_id      yang:uuid
```

- **ID and Description** uniquely identifies the detected anomaly.
- **Author Name, Type, Version and Algo-Version** describes wherever the anomaly was detected by a human or algorithm and uniquely identifies the system and version who/which detected.
- **State** describes the state of the anomaly (selected among the states defined in the state machine).
- **Symptoms** describes the identified symptoms defined in ietf-symptom-semantic-metadata.

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Status, Summary and Next steps

Status of draft-netana-nmop-network-anomaly-architecture-00

- Initial document published. Requesting feedback from the working group.

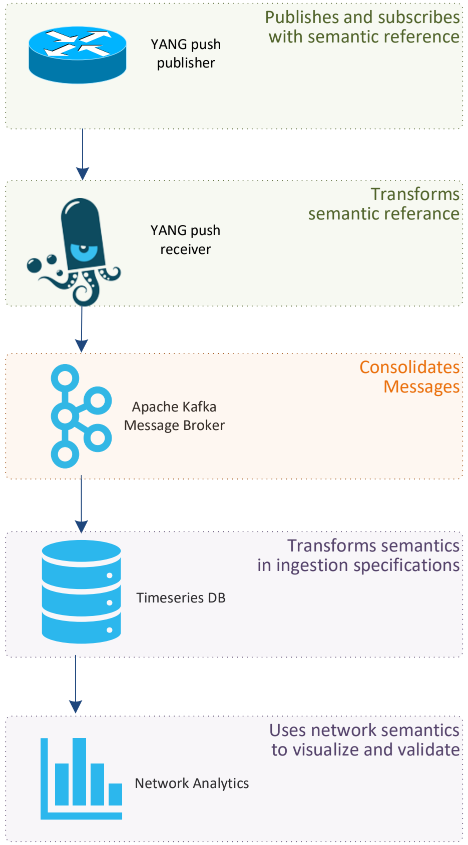
Status of draft-netana-nmop-network-anomaly-semantics-02 and draft-netana-nmop-network-anomaly-lifecycle-03

- Referred to draft-netana-nmop-network-anomaly-architecture as the main document for the architecture
- Change the term source to annotator and updated the YANG modules accordingly
- Added/updated terminology section with references to draft-ietf-nmop-terminology and draft-netana-nmop-network-anomaly-architecture
- Moved data mesh and outlier detection section to draft-netana-nmop-network-anomaly-architecture

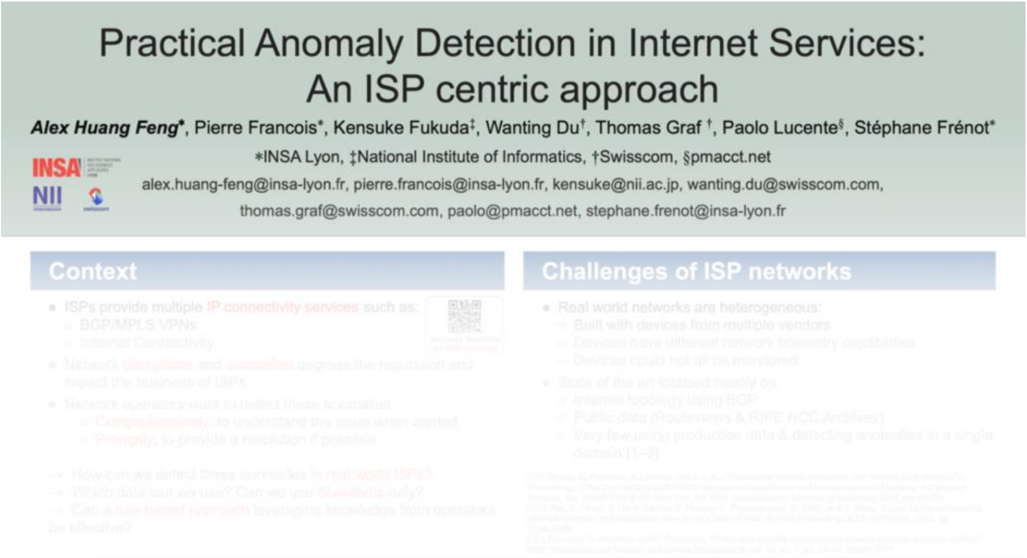
Next Steps

➢ **Request adoption for all 3 documents starting with draft-netana-nmop-network-anomaly-architecture-00.**

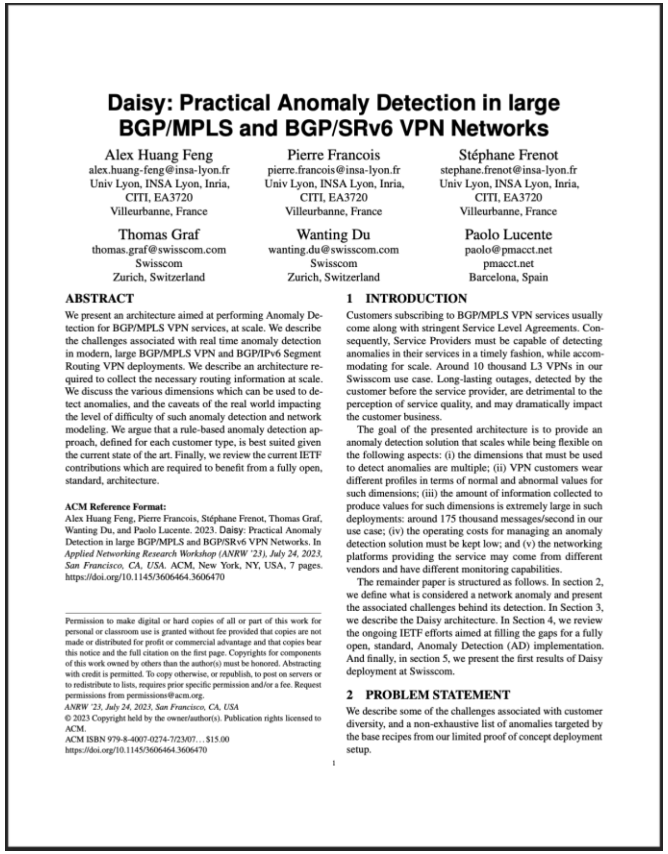
➢ **In-depth coverage at NMOP interim meeting on September 11th.**



Relevant Papers for more Details



Paper “**Practical Anomaly Detection in Internet Services: An ISP centric approach**”
accepted at AnNet’24
(in conjunction with IEEE NOMS’24)
Seoul, Korea (6–10 May 2024)
[Will be presented as a poster the May 6th 2024]



Daisy: Practical Anomaly Detection in large BGP/MPLS and BGP/SRv6 VPN Networks

Alex Huang Feng
alex.huang-feng@insa-lyon.fr
Univ Lyon, INSA Lyon, Inria, CITI, EA3720
Villeurbanne, France

Pierre Francois
pierre.francois@insa-lyon.fr
Univ Lyon, INSA Lyon, Inria, CITI, EA3720
Villeurbanne, France

Stéphane Frenot
stephane.frenot@insa-lyon.fr
Univ Lyon, INSA Lyon, Inria, CITI, EA3720
Villeurbanne, France

Thomas Graf
thomas.graf@swisscom.com
Swisscom
Zurich, Switzerland

Wanting Du
wanting.du@swisscom.com
Swisscom
Zurich, Switzerland

Paolo Lucente
paolo@pmacct.net
pmacct.net
Barcelona, Spain

ABSTRACT

We present an architecture aimed at performing Anomaly Detection for BGP/MPLS VPN services, at scale. We describe the challenges associated with real time anomaly detection in modern, large BGP/MPLS VPN and BGP/IPv6 Segment Routing VPN deployments. We describe an architecture required to collect the necessary routing information at scale. We discuss the various dimensions which can be used to detect anomalies, and the caveats of the real world impacting the level of difficulty of such anomaly detection and network modeling. We argue that a rule-based anomaly detection approach, defined for each customer type, is best suited given the current state of the art. Finally, we review the current IETF contributions which are required to benefit from a fully open, standard, architecture.

ACM Reference Format:
Alex Huang Feng, Pierre Francois, Stéphane Frenot, Thomas Graf, Wanting Du, and Paolo Lucente. 2023. Daisy: Practical Anomaly Detection in large BGP/MPLS and BGP/SRv6 VPN Networks. In *Applied Networking Research Workshop (ANRW '23), July 24, 2023, San Francisco, CA, USA.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3606464.3606470

1 INTRODUCTION

Customers subscribing to BGP/MPLS VPN services usually come along with stringent Service Level Agreements. Consequently, Service Providers must be capable of detecting anomalies in their services in a timely fashion, while accommodating for scale. Around 10 thousand L3 VPNs in our Swisscom use case. Long-lasting outages, detected by the customer before the service provider, are detrimental to the perception of service quality, and may dramatically impact the customer business.

The goal of the presented architecture is to provide an anomaly detection solution that scales while being flexible on the following aspects: (i) the dimensions that must be used to detect anomalies are multiple; (ii) VPN customers wear different profiles in terms of normal and abnormal values for such dimensions; (iii) the amount of information collected to produce values for such dimensions is extremely large in such deployments: around 175 thousand messages/second in our use case; (iv) the operating costs for managing an anomaly detection solution must be kept low; and (v) the networking platforms providing the service may come from different vendors and have different monitoring capabilities.

The remainder paper is structured as follows. In section 2, we define what is considered a network anomaly and present the associated challenges behind its detection. In Section 3, we describe the Daisy architecture. In Section 4, we review the ongoing IETF efforts aimed at filling the gaps for a fully open, standard, Anomaly Detection (AD) implementation. And finally, in section 5, we present the first results of Daisy deployment at Swisscom.

2 PROBLEM STATEMENT

We describe some of the challenges associated with customer diversity, and a non-exhaustive list of anomalies targeted by the base recipes from our limited proof of concept deployment setup.

ANRW '23, July 24, 2023, San Francisco, CA, USA

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