An Architecture for a Network Anomaly Detection Framework

draft-ietf-nmop-network-anomaly-architecture-05
draft-ietf-nmop-network-anomaly-semantics-03
draft-ietf-nmop-network-anomaly-lifecycle-03

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

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Problem Statement and Motivation

How it is being addressed in which document

Network Anomaly Detection

When operational or configurational changes in connectivity services are happening, the objective is to detect interruption at network operation faster than the users using those connectivity services

In order to achieve this objective, automation in network monitoring is required. This automation needs to monitor network changes holistically by monitoring all 3 network planes simultaneously and detect whether that change is service disruptive.

Through network incidents postmortems we network operators learn and improve so does network anomaly detection and supervised and semi-supervised machine learning. With more and more incidents the postmortem process demands automation and with the standardization of labeled network incident collaboration among network operators, vendors and academia is facilitated.

- draft-ietf-nmop-network-anomaly-architecture describes the motivation and architecture and the relationship to other two documents.
- draft-ietf-nmop-network-anomaly-semantics defines Symptom semantics to enable standardized data exchange to validate results with network engineers and improve supervised and semi-supervised machine learning systems.
- draft-ietf-nmop-network-anomaly-lifecycle describes on managing the lifecycle process, in order to facilitate network engineers to interact with the network anomaly detection system to refine the detection abilities over time.

Network Anomaly Detection Architecture

Document Updates

- Updated terminology. Change from "cause" to "trigger" based on Adrian's feedback.
- Updated Service Disruption Detection Section to cover templates.
- Changed Service Model reference from RFC 8309 to RFC 8969.
- Merged editorial input from Rüdiger, Reshad and Paul. Thanks a lot for the review!

Semantic Metadata Annotation

Document Updates

- Updated YANG modules.
  - Added "template", see [section 3.2 in Network Anomaly Detection Architecture](), and "season" into ietf-network-anomaly-symptom-cbl.
  - Added maintenance related information into ietf-network-anomaly-service-topology.
- Updated terminology. Change from "cause" to "trigger" based on Adrian's feedback.
- Added in Section 4.4 Apache AVRO data model translation.
- Completed Security Considerations according to [draft-ietf-netmod-rfc8407bis-28#appendix-B]().
- Described service model context and added normative reference to RFC 8969.
- Added Cosmos Bright Lights in Implementation status section.

```
module: ietf-network-anomaly-symptom-cbl

    augment /rsn:relevant-state/rsn:anomaly/rsn:symptom:
      +--rw action?           string
      +--rw reason?           string
      +--rw trigger?          string
      +--rw network-plane?    enumeration
      +--rw template?         string
      +--rw season?           Enumeration
```

```
module: ietf-network-anomaly-service-topology

    augment /rsn:relevant-state/rsn:service:
      +--:(l2vpn)
      |  +--rw vpn-service* [vpn-id]
      |     +--rw vpn-id                 string
      |     +--rw uri?                   inet:uri
      |     +--rw vpn-name?              string
      |     +--rw site-ids*              string
      |     +--rw change-id?             yang:uuid
      |     +--rw change-start-time?     yang:date-and-time
      |     +--rw change-end-time?       yang:date-and-time
      +--:(l3vpn)
         +--rw vpn-service* [vpn-id]
            +--rw vpn-id                 string
            +--rw uri?                   inet:uri
            +--rw vpn-name?              string
            +--rw site-ids*              string
            +--rw change-id?             yang:uuid
            +--rw change-start-time?     yang:date-and-time
            +--rw change-end-time?       yang:date-and-time
```

Network Anomaly Lifecycle

Document Updates

- Updated relevant-state YANG module
  - Added global uri, confidence-score and strategy
  - Added service container
  - Renamed anomaly grouping from anomalies to anomaly according to RFC 8407.
  - Annotator-type is now an enumeration.
- Merged terminology input from Adrian
- Completed Security Considerations according to draft-ietf-netmod-rfc8407bis-28#appendix-B.

```
module: ietf-relevant-state
  +--rw relevant-state
     +--rw id                      yang:uuid
     +--rw uri?                    inet:uri
     +--rw description?            string
     +--rw start-time              yang:date-and-time
     +--rw end-time?               yang:date-and-time
     +--rw strategy?               string
     +--rw confidence-score?       score
     +--rw concern-score           score
     +--rw (service)?
     +--rw anomaly* [id revision]
        +--rw id                      yang:uuid
        +--rw revision                yang:counter32
        +--rw uri?                    inet:uri
        +--rw state                   identityref
        +--rw description?            string
        +--rw start-time              yang:date-and-time
        +--rw end-time?               yang:date-and-time
        +--rw confidence-score?       score
        +--rw pattern?                identityref
        +--rw annotator
        |  +--rw id?                   yang:uuid
        |  +--rw name                  string
        |  +--rw version?              string
        |  +--rw annotator-type?       enumeration
        +--rw symptom!
           +--rw id                   yang:uuid
           +--rw concern-score        score
```

Network Anomaly Lifecycle and Semantic Metadata Annotation

Combined YANG Schema Tree

```
notifications:
   +---n relevant-state-notification
      +--ro publisher
      |  +--ro id?        yang:uuid
      |  +--ro name       string
      |  +--ro version?   string
      +--ro id                                 yang:uuid
      +--ro uri?                               inet:uri
      +--ro description?                       string
      +--ro start-time                         yang:date-and-time
      +--ro end-time?                          yang:date-and-time
      +--ro smcblsymptom:strategy?             string
      +--ro confidence-score?                  score
      +--ro concern-score                      score
      +--ro (service)?
      |  +--:(smtopology:l2vpn)
      |  |  +--ro smtopology:vpn-service* [vpn-id]
      |  |     +--ro smtopology:vpn-id                  string
      |  |     +--ro smtopology:uri?                    inet:uri
      |  |     +--ro smtopology:vpn-name?               string
      |  |     +--ro smtopology:site-ids*               string
      |  |     +--ro smtopology:change-id?              yang:uuid
      |  |     +--ro smtopology:change-start-time?
      |  |     |       yang:date-and-time
      |  |     +--ro smtopology:change-end-time?
      |  |             yang:date-and-time
      |  +--:(smtopology:l3vpn)
      |     +--ro smtopology:vpn-service* [vpn-id]
      |        +--ro smtopology:vpn-id                  string
      |        +--ro smtopology:uri?                    inet:uri
      |        +--ro smtopology:vpn-name?               string
      |        +--ro smtopology:site-ids*               string
      |        +--ro smtopology:change-id?              yang:uuid
      |        +--ro smtopology:change-start-time?
      |        |       yang:date-and-time
      |        +--ro smtopology:change-end-time?
      |                yang:date-and-time
```

```
notifications:
   +---n relevant-state-notification
      +--ro anomaly* [id revision]
         +--ro id                                          yang:uuid
         +--ro revision                                    yang:counter32
         +--ro uri?                                        inet:uri
         +--ro state                                       identityref
         +--ro description?                                string
         +--ro start-time
         |       yang:date-and-time
         +--ro end-time?
         |       yang:date-and-time
         +--ro confidence-score?                           score
         +--ro pattern?                                    identityref
         +--ro annotator
         |  +--ro id?               yang:uuid
         |  +--ro name              string
         |  +--ro version?          string
         |  +--ro annotator-type?   enumeration
         +--ro symptom!
         |  +--ro id                                 yang:uuid
         |  +--ro concern-score                      score
         |  +--ro smcblsymptom:action?               string
         |  +--ro smcblsymptom:reason?               string
         |  +--ro smcblsymptom:trigger?              string
         |  +--ro smcblsymptom:network-plane?        enumeration
         |  +--ro smcblsymptom:template?             string
         |  +--ro smcblsymptom:season?               Enumeration
         +--ro smtopology:vpn-node-terminations*
                 [hostname route-distinguisher]
            +--ro smtopology:hostname                    inet:host
            +--ro smtopology:route-distinguisher         string
            +--ro smtopology:peer-ip*                    inet:ip-address
            +--ro smtopology:next-hop*                   inet:ip-address
            +--ro smtopology:interface-id*               uint32
```

Shows the observed symptoms, the network dimensions triggering and connectivity service impacted.

Network Anomaly Lifecycle and Semantic Metadata Annotation

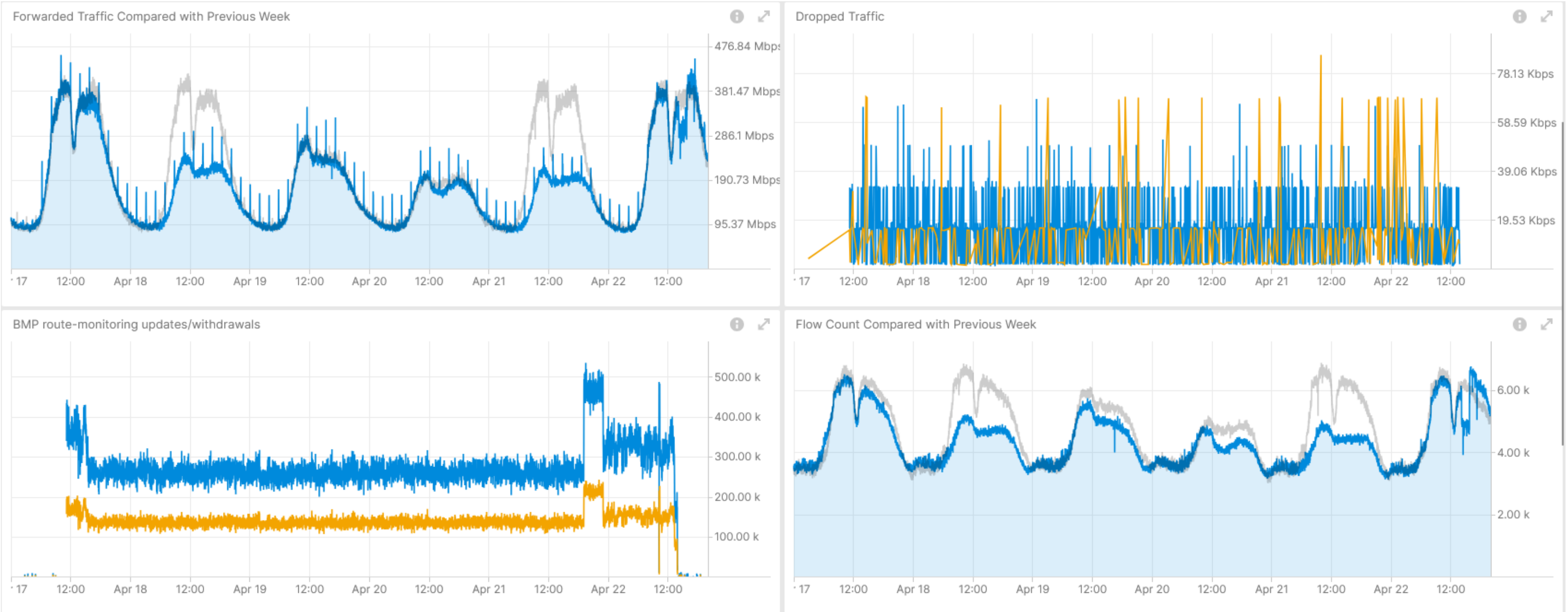
Example Message from Cosmos Bright Lights Implementation


```
{
    "id": "616963b4-1f4f-4abe-94b5-7e1354653d49",
    "uri": {
        "string": "https://pivot-url-proxy.app.zhh.sbd.corproot.net/pivot/c/926d/CBL_LC_Overview_Dev?vpn_id=64497:19313&comms=64497:19313"
    },
    "description": null,
    "startTime": 1745333220000,
    "endTime": {
        "long": 1745333280000
    },
    "confidenceScore": null,
    "concernScore": 8,
    "anomaly": [
        {
            "id": "ffdfb6d8-2a00-5219-b458-add2ce57e2db",
            "revision": 0,
            "uri": null,
            "state": "detection",
            "description": null,
            "startTime": 1745332860000,
            "endTime": {
                "long": 1745333220000
            },
            "confidenceScore": null,
            "pattern": null,
            "annotator": {
                "id": {
                    "string": "ffdfb6d8-2a00-5219-b458-add2ce57e2db"
                },
                "name": "com.swisscom.daisy.cosmos.brightlights.bmp.functions.BmpCountScoringPerWindow",
                "annotatorType": {
                    "AnnotatorType": "algorithm"
                }
            },
 "symptom": {
                "Symptom": {
                    "id": "1bee6d7e-923b-4990-b33f-208ed1bd9cf4",
                    "concernScore": 0,
                    "action": null,
                    "reason": null,
                    "trigger": null,
                    "networkPlane": null
                }
            }
        }
    ],
"vpnNodeTerminations": [
        {
            "hostname": "138.190.128.227",
            "routeDistinguisher": "2:4260047718:10440",
            "peerIp": [
                "10.94.87.138"
            ],
            "nextHop": [],
            "interfaceId": []
        }
    ],
    "service": {
        "L3VpnServiceContainer": {
            "l3VpnService": [
                {
                    "vpnId": "64497:19313",
                    "uri": {
                        "string": "https://thor-ui.thoruipp.corproot.net/cantata/lcs?dstCommunity=64497:19313"
                    },
                    "vpnName": {
                        "string": "64497:19313"
                    },
                    "siteIds": null,
                    "changeId": null,
                    "changeStartTime": null,
                    "changeEndTime": null
                }
            ]
        }
    },
    "publisher": {
        "id": "161495ba-3c0a-5f13-90ae-b907259be226",
        "name": "Brightlights - Streaming",
        "version": {
            "string": "1.0.9-alert-1"
        }
    }
}
```


Shows the observed symptoms, the network dimensions triggering and connectivity service impacted.

April 17-22th, OSPF/BGP Routing Instability

64497:471 L3 VPN – Real-Time Incident Analysis



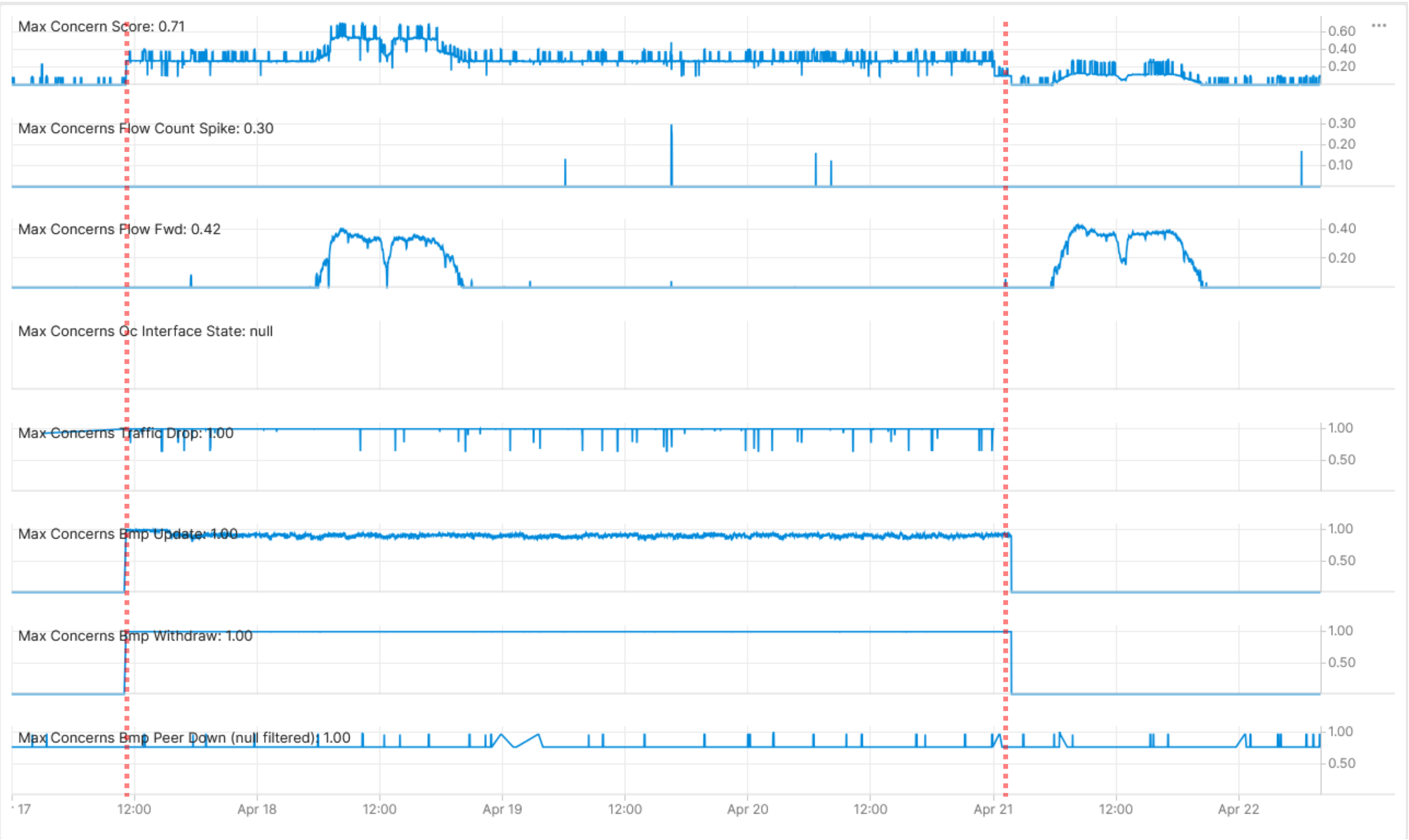
Operational Network Telemetry forwarding plane, IPFIX, BMP measured control plane metrics.

Shows traffic bad TTL, adjacency drops and traffic volume changes due to public holidays, Measured with IPFIX and Correlated with BGP VPNv4/6.

Shows constant BGP topology changes and flow count changes due to public holidays. Measured with IPFIX and Correlated with BGP VPNv4/6, BMP Adj-RIB In and Local RIB.

April 17-22th, OSPF/BGP Routing Instability

64497:471 L3 VPN – Network Anomaly Detection – Live



Cosmos Bright Lights monitoring 64497:471 L3 VPN in real-time during maintenance window.

Concern Score: 0.71
Flow Count Spike: **0.30**
Missing Traffic: **0.41**
Traffic Drop: **1.00**
BMP Peer/Interface Down: **0.96/0.00**
BMP Update/Withdrawal: **1.00/1.00**

BMP route-monitoring Update/Withdraw check recognized excessive topology changes.

BMP peer Down/Up check recognized issue with **unstable peer on another network platform..**

Interface Down/Up check did not apply.

Traffic Drop spike recognized drops due to instable routing topology.

Missing Traffic recognized traffic volume changes **due to public holidays.**

Increased or decreased Flow Count triggered sporadically **due to public holidays** flow count changes.

Overall: 2 out of 6 checks have detected the excessive routing topology changes with drops. Customer profiling related false positives see in conclusion.

April 17-22th, OSPF/BGP Routing Instability

Provider Impact Analysis – Concern Objects declare Causality

Concerning Bmp Router list

Bmp Router	Count ↓
138.190.128.227	3,337
138.190.128.226	48
138.190.128.225	24

detected BGP peer down

Time, detected peer down	Count
Apr 17, 19:36-19:37	1
peer_ip=10.94.87.130, bmp_router=138.190.128.227, rd=2:4260047718:10442	1
Apr 17, 19:37-19:38	1
peer_ip=10.94.87.130, bmp_router=138.190.128.227, rd=2:4260047718:10442	1
Apr 17, 19:38-19:39	3
peer_ip=10.94.87.130, bmp_router=138.190.128.227, rd=2:4260047718:10442	3
Apr 17, 19:39-19:40	1
peer_ip=10.94.87.130, bmp_router=138.190.128.227, rd=2:4260047718:10442	1
Apr 17, 19:40-19:41	1

Concerning node with interface status change

Node Id	Count ↓

Detected interface up

Time, detected interface up	Count

Detected interface down

Time, detected interface down	Count

Showing excessive BGP peer downs on MPLS Inter-AS Option A Platform unrelated to Incident.

Measured with BMP Adj-RIB In.

Analytical Cosmos Bright Lights observed metrics.

April 17-22th, OSPF/BGP Routing Instability

Semantic Metadata Annotation - National Holidays

National holiday information should be considered to improve accuracy of Contextual outliers for seasonal traffic volume and flow count change categorized profiles in the missing traffic and flow count spike strategies and declared in symptom semantics.

Operational Network Telemetry forwarding plane, IPFIX, BMP measured control plane metrics.

```
+--ro symptom!
        |  +--ro id                          yang:uuid
        |  +--ro concern-score               score
        |  +--ro smcblsymptom:action?        string
        |  +--ro smcblsymptom:reason?        string
        |  +--ro smcblsymptom:trigger?       string
        |  +--ro smcblsymptom:network-plane? enumeration
        |  +--ro smcblsymptom:strategy?      string
        |  +--ro smcblsymptom:template?      string
        |  +--ro smcblsymptom:season?        Enumeration
```

Next Steps and Remaining Issues

Feedback on latest changes, YANG Doctors review, SIMAP Integration

Next Steps

- Requesting working group feedback on the updated YANG models and editorial changes.
- Request YANG doctors review for draft-ietf-nmop-network-anomaly-semantics-03 and draft-ietf-nmop-network-anomaly-lifecycle-03.

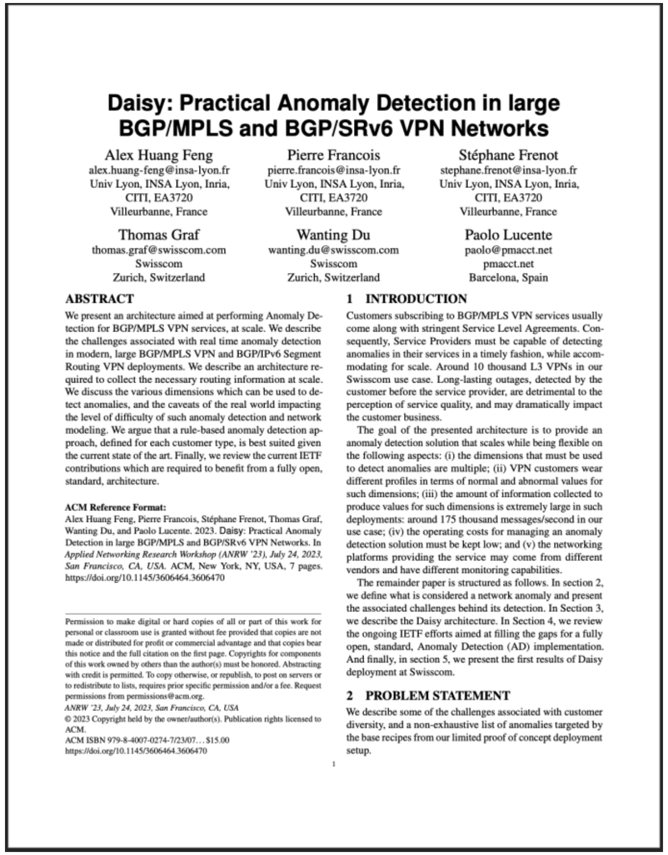
Remaining Issue

- Clarify with working group relationship between rule-based and knowledge-based.
- smtopology:vpn-node-terminations defines hostname, route-distinguisher, peer-ip and next-hop and interface-id instead of augmenting /nw:networks/nw:network/nw:node:termination-point from Section 4.2 of RFC 8345.
- How should we address to achieve Postmortem Replay in SIMAP, Section 3.9 of draft-ietf-nmop-simap-concept.

Relevant Papers for more Details

Practical Anomaly Detection in Internet Services: An ISP centric approach

Alex Huang Feng*, Pierre Francois*, Kensuke Fukuda‡, Wanting Du†, Thomas Graf†, Paolo Lucente§, Stéphane Frénot*



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

Alex Huang Feng, Pierre Francois, Stéphane Frenot, Thomas Graf, Wanting Du, Paolo Lucente

Paper "**Practical Anomaly Detection in Internet Services: An ISP centric approach**"
Published at AnNet Workshop (In conjunction with IEEE NOMS)
Seoul, South Korea (6–10 May 2024)
Open access: https://hal.science/hal-04655324

Paper "**Daisy: Practical Anomaly Detection in large BGP/MPLS and BGP/SRv6 VPN Networks**" published at ACM/IRTF ANRW'23
San Francisco, USA (24 July 2023)
Open access: http://hal.science/hal-04307611