An Architecture for YANG-Push to Message Broker Integration

draft-ietf-nmop-yang-message-broker-integration

Motivation and architecture of a native
YANG-Push notifications and YANG Schema integration
into Message Broker and YANG Schema Registry

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IETF YANG-Push

A 22 years journey

2002

IAB Workshop

Defines operators' requirements in RFC 3535 to lifecycle CLI and SNMP. YANG, Netconf and Restconf development started.

2010

YANG 1.0

Specified in RFC 6020. 1.1 in RFC 7950.

2015

IETF YANG-Push Specification Started

Development of RFC 8639 and RFC 8641 started at IETF NETCONF.

2017

gNMI

gNMI was presented to IETF NETCONF and implementations started at major network vendors.

2019

IETF YANG-Push Specification Finished

Development of RFC 8639 and RFC 8641 concluded at IETF NETCONF without any major network vendor implementations.

2022

Data Mesh Integration

Vendor-specific implementations and IETF YANG-Push are hard to manage. New requirements emerged for integrating with the message broker and an automated data processing chain. New specifications are proposed to resolve these challenges.

2024

IETF YANG-Push Major Implementations Started

Questions arise. Proposing a simplified IETF YANG-Push and an Agile Incremental Driven Development.

Handling Operational YANG Modelled Data

State of the Union

Nowadays network operators are using **machine and human readable YANG** RFC 7950 to model their configurations and obtain YANG modelled data from their networks.

Network operators organize their data in a Data Mesh where a message broker such as Apache Kafka facilitates the exchange of messages among data processing components.

Today, subscribing to a YANG datastore, publishing a YANG modeled notifications message from the network and viewing the data in a time series database, **manual labor is needed to perform data transformation** to make a message broker and its data processing components with YANG notifications interoperable.

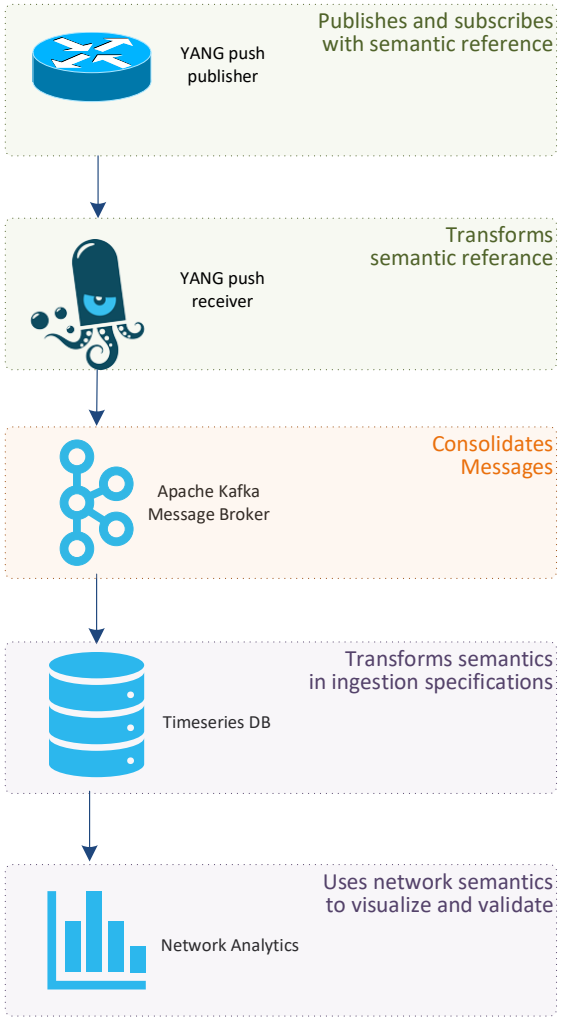
« Even though YANG is intented to ease data management, **this promise has not yet been fulfilled** for Network Telemetry RFC 9232 »

From YANG-Push to Network Analytics

Aiming for an automated data processing pipeline

- **A network operator aims for:**
  - An **automated data processing pipeline** which starts with YANG-Push, consolidates at Data Mesh and ends at Network Analytics.
  - Operational metrics where **IETF defines the semantics.**
  - Analytical metrics where **network operators gain actionable insights.**

- **We achieve this by integrating YANG-Push into Data Mesh to:**
  - Produce metrics from networks **with timestamps when network events were observed.**
  - Hostname, publisher ID and sequence numbers help us to understand **from where metrics were exported and measure its delay and loss.**
  - Forward **metrics unchanged** from networks
  - **Learn semantics** from networks and validate messages.
  - **Control semantic** changes end to end.



We have a dream

Digital Twin at your fingertips

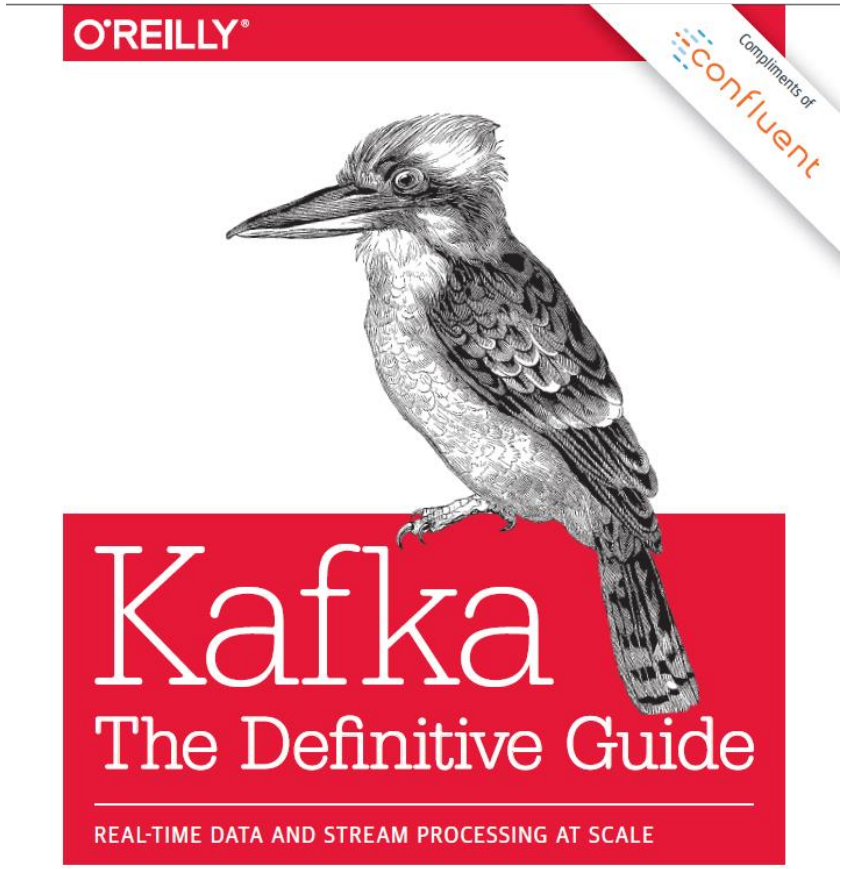
« Imagine that your entire life as network engineer you have logged into routers to perform show commands to get a glimpse into the current state of your networks. »

« Suddenly you see your colleague on the right querying the current network state in seconds directly from a real-time data stream. No access to routers needed. No databases needed. »

"NASA Mission Control Digital Twin in the 60s, Digital Twin is not Rocket Science"

Terminology (1)
Message Broker

- **Subject:** A named communication channel where a schema registry assigned schema id is associated.
- **Topic:** A communication channel for publishing and subscribing messages between producer and consumer with one or more subjects.
- **Topic Compaction:** The act of compressing messages in a topic to the latest state.
- **Partition:** Messages in a topic are spread over hash buckets where a hash bucket refers to a partition.
- **Message:** A piece of structured data sent between data processing components to facilitate communication in a distributed system
- **Message Key:** Metadata associated with a message to facilitate deterministic hash bucketing.
- **Segment:** A physical file containing multiple messages.



https://www.confluent.io/thank-you/resources/ebook/kafka-the-definitive-guide/

Terminology (2)

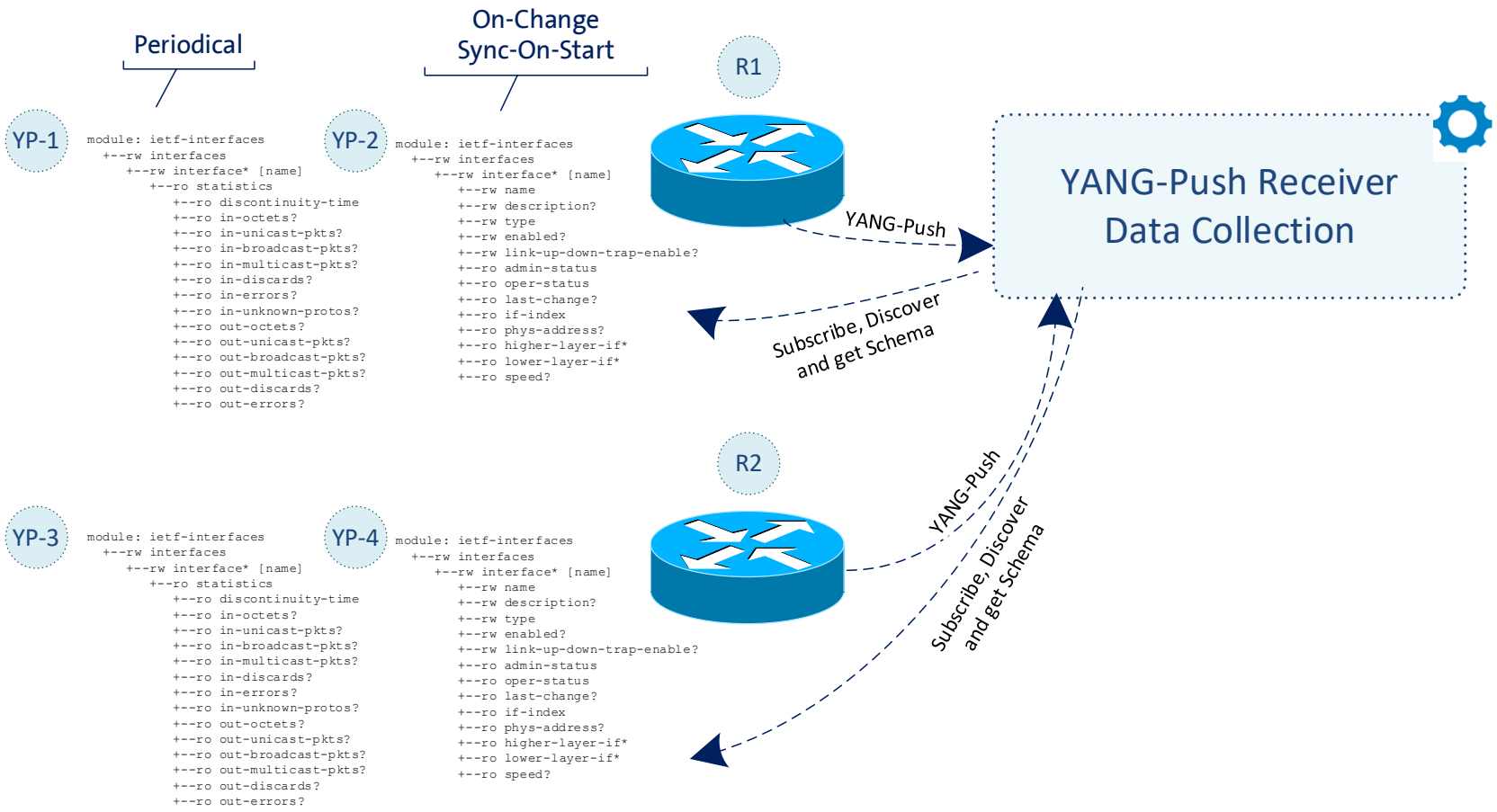
YANG Data Taxonomy and Index

- **Dimensional Data:** Structured information in a data store [Ralph Kimball]. Example: YANG with data taxonomy.
- **Data Taxonomy:** Is a hierarchical system for classifying and organizing data into categories and subcategories
- **YANG Schema Tree:** The definition hierarchy specified within a module.
- **YANG Schema Node:** A node in the schema tree.
- **YANG Item Identifiers:** Section 3.3 in RFC 9254 defines unique text-based identifiers for each YANG element including YANG schema nodes.
- **YANG index:** Is a subset of YANG item identifiers containing only YANG schema node identifiers.

```
module: ietf-interfaces
     +--rw interfaces
        +--rw interface* [name]
           +--rw name                            string
           +--rw description?                    string
           +--rw type                            identityref
           +--rw enabled?                        boolean
           +--rw link-up-down-trap-enable?       enumeration {if-mib}?
           +--ro admin-status                    enumeration {if-mib}?
           +--ro oper-status                     enumeration
           +--ro last-change?                    yang:date-and-time
           +--ro if-index                        int32 {if-mib}?
           +--ro phys-address?                   yang:phys-address
           +--ro higher-layer-if*                interface-ref
           +--ro lower-layer-if*                 interface-ref
           +--ro speed?                          yang:gauge64
           +--ro statistics
              +--ro discontinuity-time    yang:date-and-time
              +--ro in-octets?            yang:counter64
              +--ro in-unicast-pkts?      yang:counter64
              +--ro in-broadcast-pkts?    yang:counter64
              +--ro in-multicast-pkts?    yang:counter64
              +--ro in-discards?          yang:counter32
              +--ro in-errors?            yang:counter32
              +--ro in-unknown-protos?    yang:counter32
              +--ro out-octets?           yang:counter64
              +--ro out-unicast-pkts?     yang:counter64
              +--ro out-broadcast-pkts?   yang:counter64
              +--ro out-multicast-pkts?   yang:counter64
              +--ro out-discards?         yang:counter32
              +--ro out-errors?           yang:counter32
```

YANG-Push

Discover and Subscribe to YANG metrics



From discovering YANG-Push subscription capabilities defined in RFC 9196, subscribing interesting metrics periodical (**statistics**), on-change (**state changes**) or on-change with sync-on-start (**states**) defined in RFC 8641.

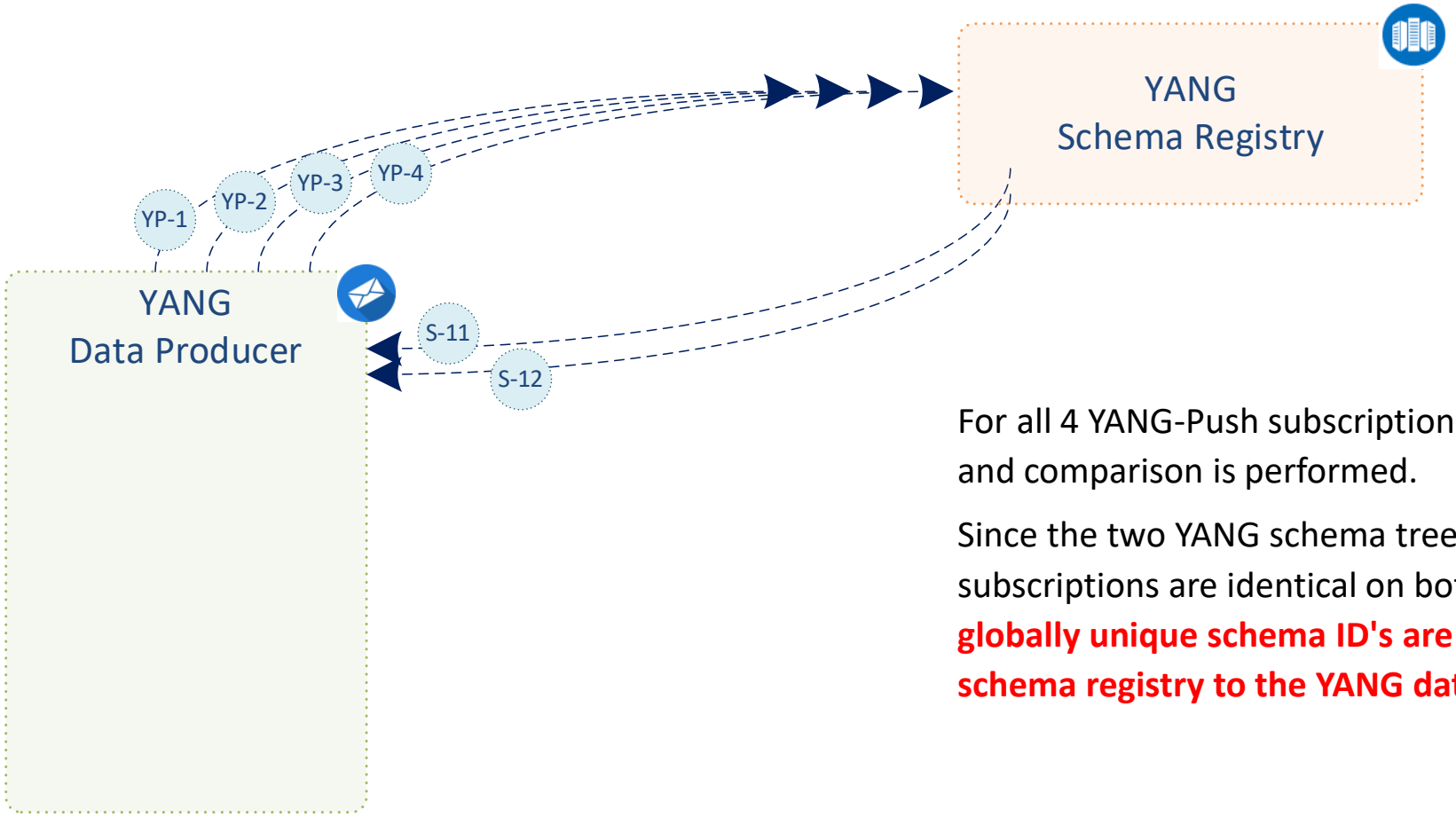
Each subscription refers to network node, datastore (RFC 8342) and a schema tree.

In this RFC 8343 example ietf-interface statistics are subscribed periodically and ietf-interface states on-change sync-on-start. **YANG-Push subscription ID's are per network node significant.**

Data Collection obtains for each subscription the YANG schema tree by leveraging <get-schema> (RFC 6022), YANG Library (RFC 8525) and draft-ietf-netconf-yang-library-augmentedby.

YANG Schema Registry

From 4 subscription ID's to 2 schema ID's

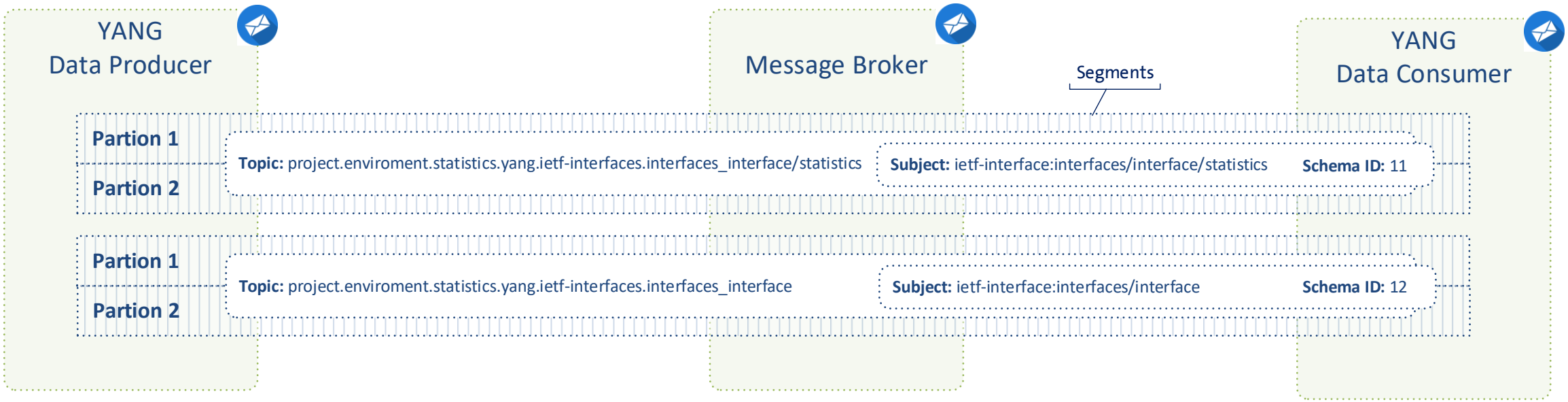


For all 4 YANG-Push subscriptions, YANG schema registration and comparison is performed.

Since the two YANG schema trees for both YANG-Push subscriptions are identical on both network nodes, **two YANG globally unique schema ID's are being issued from the YANG schema registry to the YANG data producer.**

Message Broker

Topics, Subjects, Partitions, Segments and Message Keys



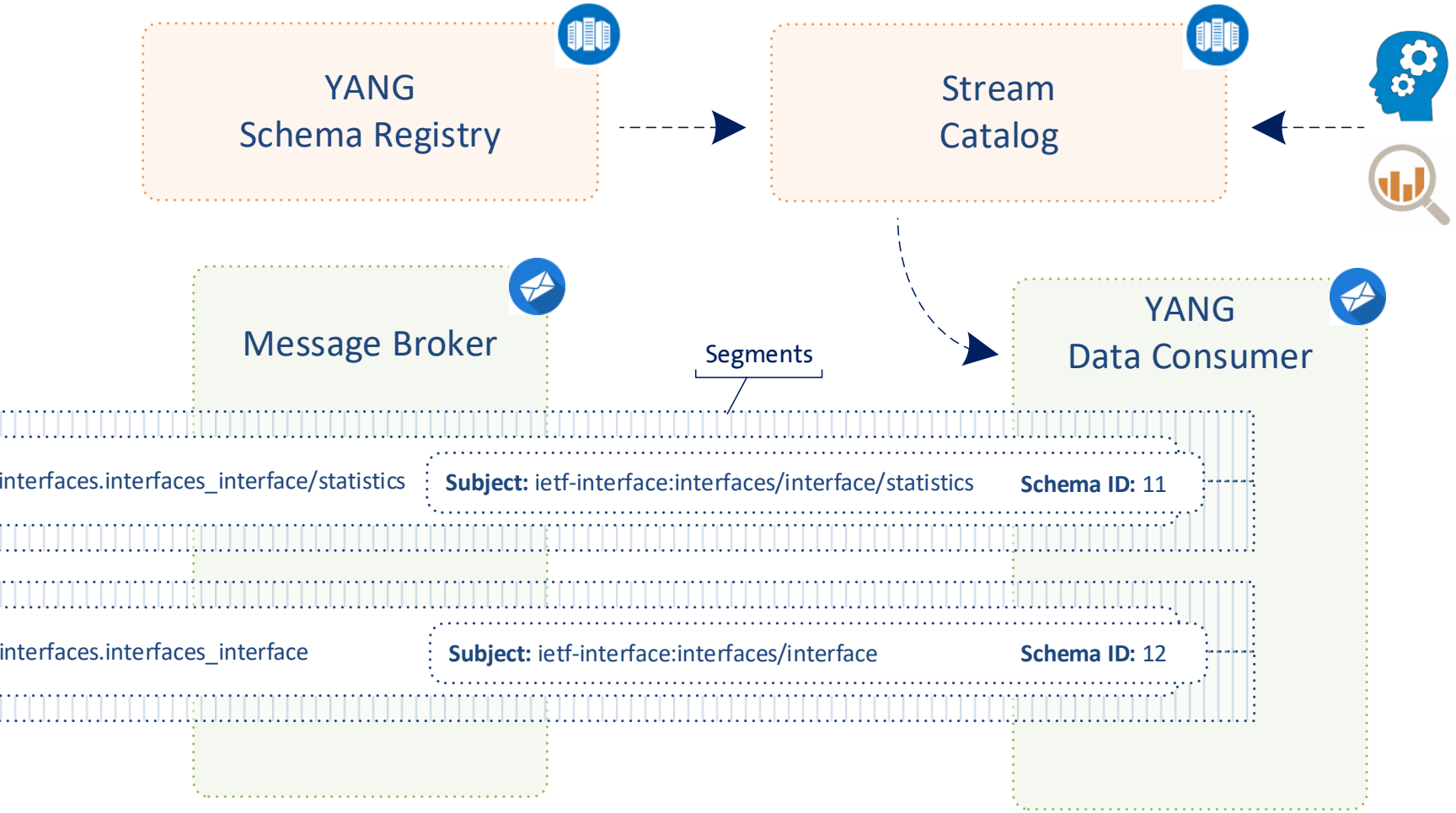
The YANG data producer creates for each YANG schema a new message broker topic, a message key and defines the number of partitions being used for the topic.

It serializes the message with the previously generated message key and message content according to draft-ietf-nmop-message-broker-telemetry-message.

Each message is prefixed with the previously obtained schema ID representing a unique message subject. The messages are distributed according to the hashed message key across the partitions into continuous segments.

YANG Data Consumption

Discover and Subscribe to YANG metrics



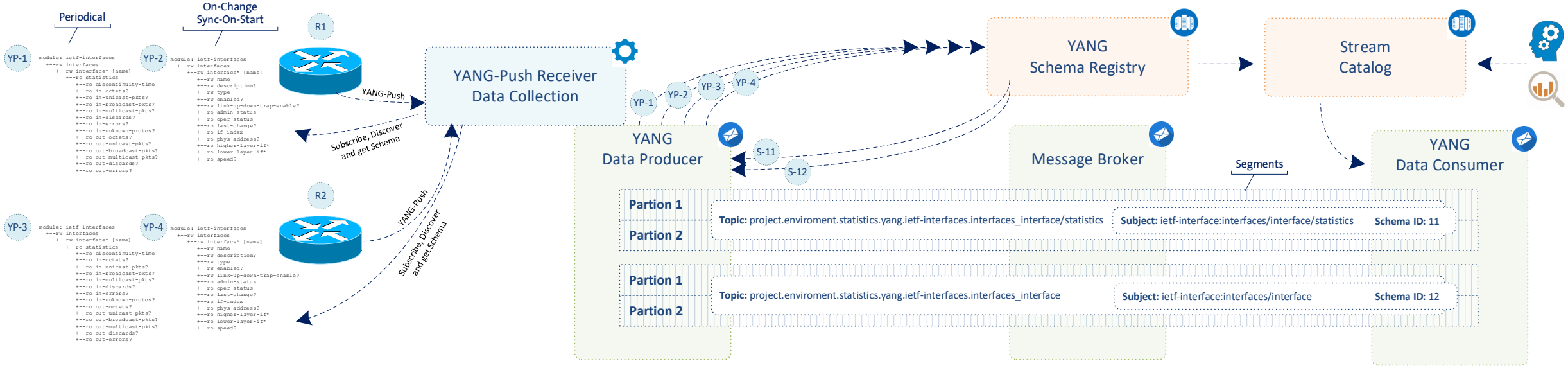
A user or AI application/agent subscribes discovers through the stream catalog interesting metrics and subscribes to message broker topic.

More than one topic can be consumed at once by using a wildcard such as: project.enviroment.states.yang.* to consume all YANG state metrics.

The consumer hashes the message key and applies modulo with the number of partitions to determine the partition it needs to consume from to obtain messages with desired message key.

Fully YANG aware Data Pipeline

From network nodes to message broker nodes



At the YANG data producer, thanks to the YANG awareness to the YANG data producer and the YANG schema registry, **for each unique YANG schema tree a message broker topic and subject is being created, and messages are being indexed and hashed according to the message key**.

At the message broker, thanks to the dedicated topic per YANG schema and its message key, **YANG state metrics can be compacted to the latest state; reducing the number of stored messages.**

At the YANG data consumer, thanks to the YANG awareness of the stream catalog and consumer, a specific topic, partition and subject can be consumed for the interested YANG metrics; **reducing the number of messages to be consumed.**

Addressing YANG Specification and Integration Gaps

9 documents at NMOP, NETCONF and NETMOD

YANG-Push Transport Gaps:

Passed working group last call. Moving to IESG

- UDP-based Transport for Configured Subscriptions
  draft-ietf-netconf-udp-notif
- Subscription to Distributed Notifications
  draft-ietf-netconf-distributed-notif

YANG-Push Specifications Gaps:

Passed working group adoption call.

- YANG Notification Transport Capabilities
  draft-ietf-netconf-yp-transport-capabilities
- Extensible YANG model for YANG-Push Notifications
  draft-ietf-netconf-notif-envelope
- Validating anydata in YANG Library context
  draft-netana-nmop-yang-anydata-validation

YANG-Push Integration Gaps and Arch:

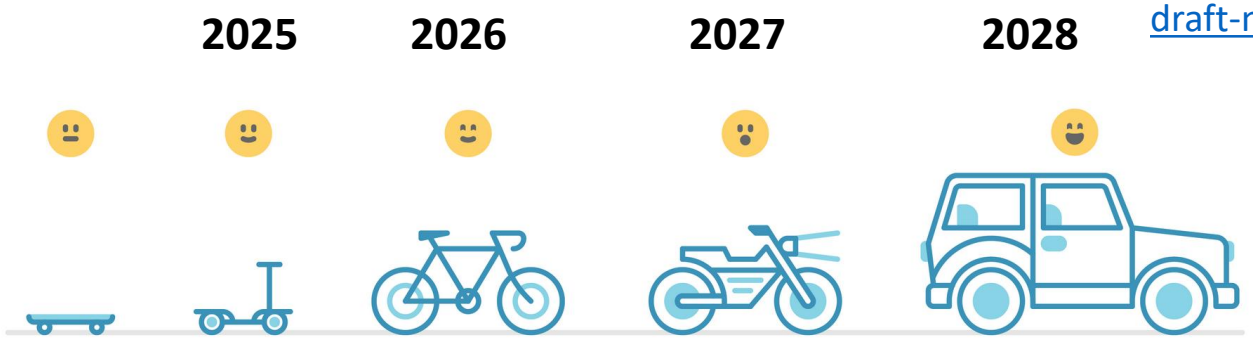
- Support of Versioning in YANG Notifications Subscription
  draft-ietf-netconf-yang-notifications-versioning
- Augmented-by Addition into the IETF-YANG-Library
  draft-ietf-netconf-yang-library-augmentation

YANG-Push Simplification:

- YANG-Push Operational Data Observability Enhancements
  draft-wilton-netconf-yp-observability

YANG-Push Message Broker:

- An Architecture for YANG-Push to Message Broker Integration
  draft-ietf-nmop-yang-message-broker-integration
- Extensible YANG Model for Network Telemetry Notifications
  draft-ietf-nmop-message-broker-telemetry-message
- YANG Message Keys for Message Broker Integration
  draft-netana-nmop-yang-message-broker-message-key



IETF YANG-Push Implementations

Incremental development…

MVP 1 - Works

4 major vendor implementations finalized.

- draft-ietf-netconf-udp-notif transport (with segmentation option) and notifications encoded in RFC 7951 IETF-JSON.
- RFC 8641 periodic subscription with anchor-time configurable in ietf-subscribed-notifications.
- YANG notifications as defined in draft-netana-netconf-notif-envelope, YANG module name, version and yang-library-content-id as in draft-ietf-netconf-yang-notifications-versioning and notification capabilities (RFC 9196) discoverable as defined in their documents.
- YANG-Library as defined in RFC 8525 and draft-ietf-netconf-yang-library-augmentedby.

MVP 2 – Scales and Secures

2 major vendor implementations started.

- Distributed notifications as defined in draft-ietf-netconf-distributed-notif.
- YANG notifications encoded in CBOR (named identifiers) as defined in RFC 9254.
- YANG notifications DTLS (1.2 MUST RFC 6347, 1.3 SHOULD RFC 9147) encrypted as defined in draft-ietf-netconf-udp-notif.

MVP 3 - Optimizes

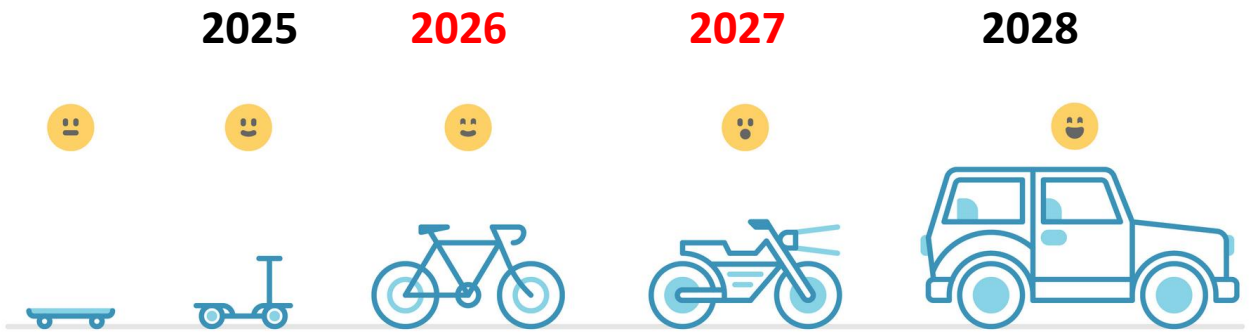
- RFC 8641 on-change subscription configurable in ietf-subscribed-notifications.
- RFC 8641 on-change and periodical subscription in RFC 9196 defined capabilities discoverable.
- draft-ietf-netconf-udp-notif transport, encoding and encryption capabilities (RFC 9196) discoverable with draft-ietf-netconf-yp-transport-capabilities.

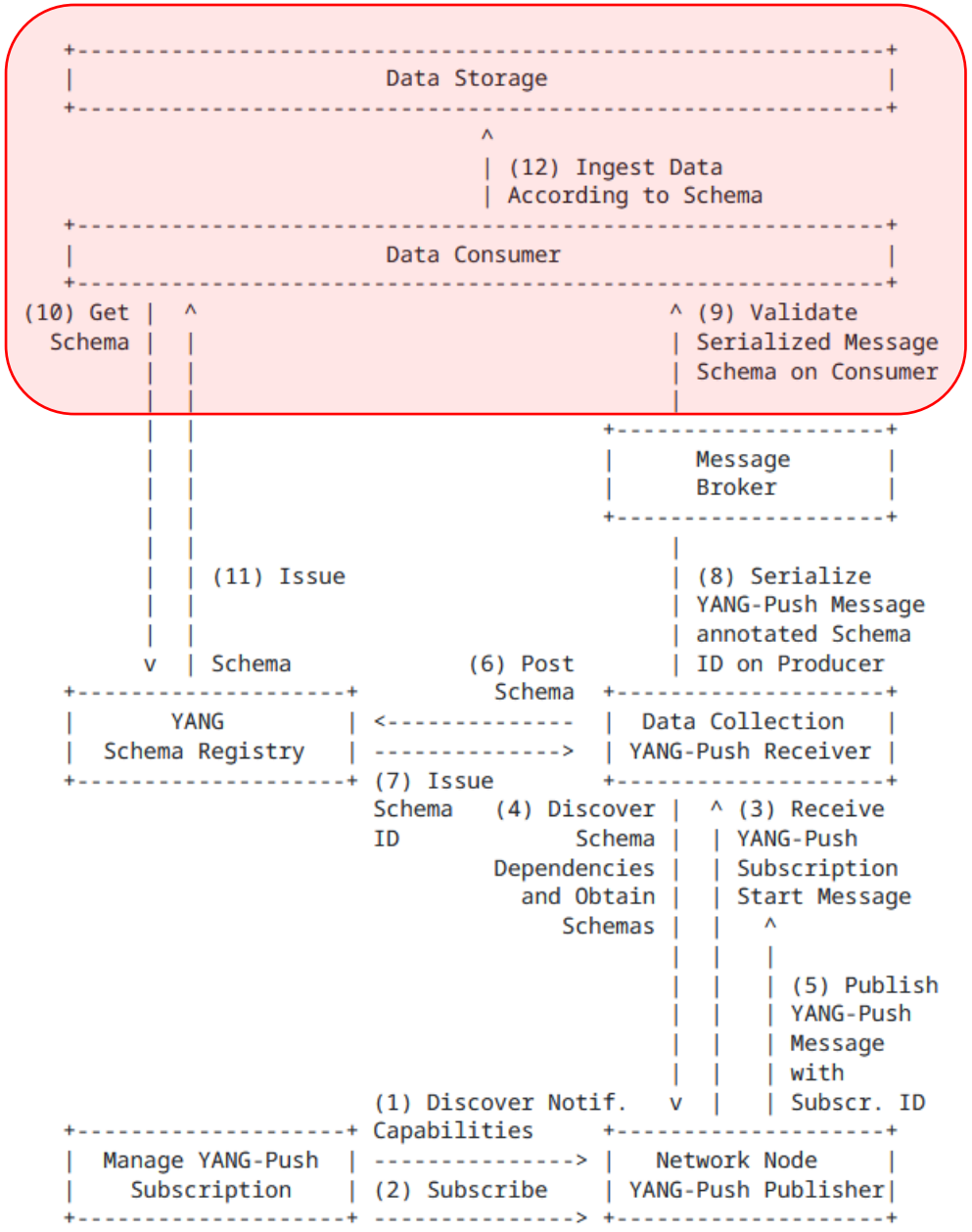
Part 2

Our collaboration goes into the next step in 2026

This allows Swisscom

to transition from SNMP to YANG





IETF YANG Model Implementations

Incremental development…

"Starting 2026, Swisscom onboards new network platforms with YANG-Push only. Initiating the SNMP to YANG lifecycle and the standardization of YANG models."

MVP 2 – Physical & Essential

Already supported by OLT MA5800.

- ietf-interfaces.yang (inventory, state and statistic)
- ietf-hardware.yang (inventory, state and statistic)
- ietf-alarms.yang (state)
- ieee802-dot1ab-lldp.yang (inventory and state)

MVP 3 – Logical Relationships

- ieee802-dot1ax.yang (inventory, state and statistic)
- ietf-bfd-ip-sh.yang (state)
- ietf-bfd-ip-mh.yang (state)
- ietf-bfd-lag.yang (state)
- ietf-isis.yang (state)

Gabriele Di Piazza and Markus Reber signing the Network Analytics MoU at MWC 2025

Blue Planet and Swisscom signed Network Analytics MoU

Thomas Graf
Distinguished Network Engineer and Network Analytics Architect at Swisscom

March 7, 2025

Dear colleagues,

I like to share a highlight of the 2025 Mobile World Congress.

It is a great honor and pleasure to announce that Blue Planet and Swisscom signed a Memorandum of Understanding in Network Analytics, collaborating in the area of:

• YANG-Push Messaging Integration into Apache Kafka Message Broker

Both companies understand the importance of moving network management lifecycle from using SNMP to using YANG for seamless integration into today's Data Mesh Big Data architectures.

RFC 8343 – ietf-interfaces.yang

YANG Data Model for Interface Management

```
module: ietf-interfaces
  +--rw interfaces
     +--rw interface* [name]
        +--rw name                            string
        +--rw description?                    string
        +--rw type                            identityref
        +--rw enabled?                        boolean
        +--rw link-up-down-trap-enable?       enumeration {if-mib}?
        +--ro admin-status                    enumeration {if-mib}?
        +--ro oper-status                     enumeration
        +--ro last-change?                    yang:date-and-time
        +--ro if-index                        int32 {if-mib}?
        +--ro phys-address?                   yang:phys-address
        +--ro higher-layer-if*                interface-ref
        +--ro lower-layer-if*                 interface-ref
        +--ro speed?                          yang:gauge64
        +--ro statistics
           +--ro discontinuity-time     yang:date-and-time
           +--ro in-octets?             yang:counter64
           +--ro in-unicast-pkts?       yang:counter64
           +--ro in-broadcast-pkts?     yang:counter64
           +--ro in-multicast-pkts?     yang:counter64
           +--ro in-discards?           yang:counter32
           +--ro in-errors?             yang:counter32
           +--ro in-unknown-protos?     yang:counter32
           +--ro out-octets?            yang:counter64
           +--ro out-unicast-pkts?      yang:counter64
           +--ro out-broadcast-pkts?    yang:counter64
           +--ro out-multicast-pkts?    yang:counter64
           +--ro out-discards?          yang:counter32
           +--ro out-errors?            yang:counter32
```

With IETF YANG-Push we like to subscribe

with on-change sync-on-start

- For inventory and alert use cases the state of the interface.

and periodically

- For performance measurement use cases the interface statistics.

RFC 8348 – ietf-hardware.yang

YANG Data Model for Hardware Management

```
module: ietf-hardware
  +--rw hardware
     +--ro last-change?   yang:date-and-time
     +--rw component* [name]
        +--rw name                string
        +--rw class               identityref
        +--ro physical-index?     int32 {entity-mib}?
        +--ro description?        string
        +--rw parent?             -> ../../component/name
        +--rw parent-rel-pos?     int32
        +--ro contains-child*     -> ../../component/name
        +--ro hardware-rev?       string
        +--ro firmware-rev?       string
        +--ro software-rev?       string
        +--ro serial-num?         string
        +--ro mfg-name?           string
        +--ro model-name?         string
        +--rw alias?              string
        +--rw asset-id?           string
        +--ro is-fru?             boolean
        +--ro mfg-date?           yang:date-and-time
        +--rw uri*                inet:uri
        +--ro uuid?               yang:uuid
        +--rw state {hardware-state}?
        |  +--ro state-last-changed?   yang:date-and-time
        |  +--rw admin-state?          admin-state
        |  +--ro oper-state?           oper-state
        |  +--ro usage-state?          usage-state
        |  +--ro alarm-state?          alarm-state
        |  +--ro standby-state?        standby-state
        +--ro sensor-data {hardware-sensor}?
           +--ro value?                  sensor-value
           +--ro value-type?             sensor-value-type
           +--ro value-scale?            sensor-value-scale
           +--ro value-precision?        sensor-value-precision
           +--ro oper-status?            sensor-status
           +--ro units-display?          string
           +--ro value-timestamp?        yang:date-and-time
           +--ro value-update-rate?      uint32
```

With IETF YANG-Push we like to subscribe

with on-change sync-on-start

- For inventory use cases the state of the hardware.
- For alert use cases the hardware state change notifications.

and periodically

- For performance measurement use cases the hardware sensor-data.

```
  notifications:
    +---n hardware-state-change
    +---n hardware-state-oper-enabled {hardware-state}?
    |  +--ro name?          -> /hardware/component/name
    |  +--ro admin-state?   -> /hardware/component/state/admin-state
    |  +--ro alarm-state?   -> /hardware/component/state/alarm-state
    +---n hardware-state-oper-disabled {hardware-state}?
       +--ro name?          -> /hardware/component/name
       +--ro admin-state?   -> /hardware/component/state/admin-state
       +--ro alarm-state?   -> /hardware/component/state/alarm-state
```

RFC 8632 – ietf-alarms.yang

YANG Data Model for Alarm Management

```
notifications:
    +---n alarm-notification
       |  +--ro resource                  resource
       |  +--ro alarm-type-id             alarm-type-id
       |  +--ro alarm-type-qualifier?     alarm-type-qualifier
       |  +--ro alt-resource*             resource
       |  +--ro related-alarm* [resource alarm-type-id alarm-type-
qualifier] {alarm-correlation}?
       |  |  +--ro resource                  -> /alarms/alarm-
list/alarm/resource
       |  |  +--ro alarm-type-id             -> /alarms/alarm-
list/alarm[resource=current()/../resource]/alarm-type-id
       |  |  +--ro alarm-type-qualifier      -> /alarms/alarm-
list/alarm[resource=current()/../resource][alarm-type-
id=current()/../alarm-type-id]/alarm-type-qualifier
       |  +--ro impacted-resource*        resource {service-impact-
analysis}?
       |  +--ro root-cause-resource*      resource {root-cause-analysis}?
       |  +--ro time                      yang:date-and-time
       |  +--ro perceived-severity        severity-with-clear
       |  +--ro alarm-text                alarm-text
       +---n alarm-inventory-changed
```

With IETF YANG-Push we like to subscribe

with on-change

- For alert use cases the alarm notifications.

IEEE LLDP – ieee802-dot1ab-lldp.yang

YANG Data Model for LLDP Neighbor Discovery

```
module: ieee802-dot1ab-lldp
  +--rw lldp
     +--ro local-system-data
     |  +--ro chassis-id-subtype?                 ieee:chassis-id-subtype-type
     |  +--ro chassis-id?                         ieee:chassis-id-type
     |  +--ro system-name?                        string
     |  +--ro system-description?                 string
     |  +--ro system-capabilities-supported?      lldp-types:system-capabilities-map
     |  +--ro system-capabilities-enabled?        lldp-types:system-capabilities-map
     +--rw port* [name dest-mac-address]
        +--rw name                              if:interface-ref
        +--rw dest-mac-address                  ieee:mac-address
        +--ro port-id?                          ieee:port-id-type
        +--ro remote-systems-data* [time-mark remote-index]
           +--ro time-mark                            yang:timeticks
           +--ro remote-index                         uint32
           +--ro remote-too-many-neighbors?           boolean
           +--ro remote-changes?                      boolean
           +--ro chassis-id-subtype?                  ieee:chassis-id-subtype-type
           +--ro chassis-id?                          ieee:chassis-id-type
           +--ro port-id-subtype?                     ieee:port-id-subtype-type
           +--ro port-id?                             ieee:port-id-type
           +--ro port-desc?                           string
           +--ro system-name?                         string
           +--ro system-description?                  string
           +--ro system-capabilities-supported?       lldp-types:system-capabilities-map
           +--ro system-capabilities-enabled?         lldp-types:system-capabilities-map
```

With IETF YANG-Push we like to subscribe

with on-change sync-on-start

- For inventory use cases the local and remote-systems-data.

IEEE dot1ax – ieee802-dot1ax.yang

YANG Data Model for LAG Interface Management

```
module: ieee802-dot1ax
  +--rw lag-system
     +--rw aggregating-system* [agg-system]
        +--rw agg-system          string
        +--rw system-id?          ieee:mac-address
        +--rw system-priority?    uint32

  augment /if:interfaces/if:interface:
    +--rw aggregator
       +--rw name?                          string
       +--rw agg-system-name?               string
       +--rw admin-state?                   enumeration
       +--rw link-up-down-notification?     enumeration
       +--rw collector-max-delay?           int16
       +--rw aggregator-lacp
          +--rw actor-admin-key?    int16

  augment /if:interfaces/if:interface:
    +--rw aggregation-port
       +--rw aggregation-port-lacp
          +--rw actor-system-priority?           int16
          +--rw actor-admin-key?                 int16
          +--rw partner-admin-system-priority?   int16
          +--rw partner-admin-system-id?         ieee:mac-address
          +--rw partner-admin-key?               int16
          +--rw actor-port-priority?             int16
          +--rw partner-admin-port?              int16
          +--rw partner-admin-port-priority?     int16
          +--rw actor-admin-state?               bits
          +--rw partner-admin-state?             bits
```

With IETF YANG-Push we like to subscribe

with on-change sync-on-start

- For inventory use cases the state of the hardware.

RFC 9127 – ietf-bfd.yang

YANG Data Model for Bidirectional Forwarding Detection

BFD IP Single-Hop Hierarchy

https://datatracker.ietf.org/doc/html/rfc9127#section-2.6

```
  notifications:
    +---n singlehop-notification
       +--ro local-discr?                   discriminator
       +--ro remote-discr?                  discriminator
       +--ro new-state?                     state
       +--ro state-change-reason?           iana-bfd-types:diagnostic
       +--ro time-of-last-state-change?     yang:date-and-time
       +--ro dest-addr?                     inet:ip-address
       +--ro source-addr?                   inet:ip-address
       +--ro session-index?                 uint32
       +--ro path-type?                     identityref
       +--ro interface?                     if:interface-ref
       +--ro echo-enabled?                  boolean
```

BFD-over-LAG Hierarchy

https://datatracker.ietf.org/doc/html/rfc9127#section-2

```
  notifications:
    +---n lag-notification
       +--ro local-discr?                   discriminator
       +--ro remote-discr?                  discriminator
       +--ro new-state?                     state
       +--ro state-change-reason?           iana-bfd-types:diagnostic
       +--ro time-of-last-state-change?     yang:date-and-time
       +--ro dest-addr?                     inet:ip-address
       +--ro source-addr?                   inet:ip-address
       +--ro session-index?                 uint32
       +--ro path-type?                     identityref
       +--ro lag-name?                      if:interface-ref
       +--ro member-link?                   if:interface-ref
```

With IETF YANG-Push we like to subscribe

with on-change sync-on-start

- For alert use cases the hardware state notifications.

BFD IP Multihop Hierarchy

https://datatracker.ietf.org/doc/html/rfc9127#section-2.7

```
  notifications:
    +---n multihop-notification
       +--ro local-discr?                   discriminator
       +--ro remote-discr?                  discriminator
       +--ro new-state?                     state
       +--ro state-change-reason?           iana-bfd-types:diagnostic
       +--ro time-of-last-state-change?     yang:date-and-time
       +--ro dest-addr?                     inet:ip-address
       +--ro source-addr?                   inet:ip-address
       +--ro session-index?                 uint32
       +--ro path-type?                     identityref
```

RFC 9130 – ietf-isis.yang

YANG Data Model for the IS-IS Protocol

```
notifications:
  +---n database-overload
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                 control-plane-protocols/
  |  |                                 control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro overload?                enumeration
  +---n if-state-change
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                 control-plane-protocols/
  |  |                                 control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--ro interface-level?         level
  |  +--ro extended-circuit-id?     extended-circuit-id
  |  +--ro state?                   if-state-type
  +---n adjacency-state-change
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                 control-plane-protocols/
  |  |                                 control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--ro interface-level?         level
  |  +--ro extended-circuit-id?     extended-circuit-id
  |  +--ro neighbor?                string
  |  +--ro neighbor-system-id?      system-id
  |  +--ro state?                   adj-state-type
  |  +--ro reason?                  string
```

With IETF YANG-Push we like to subscribe

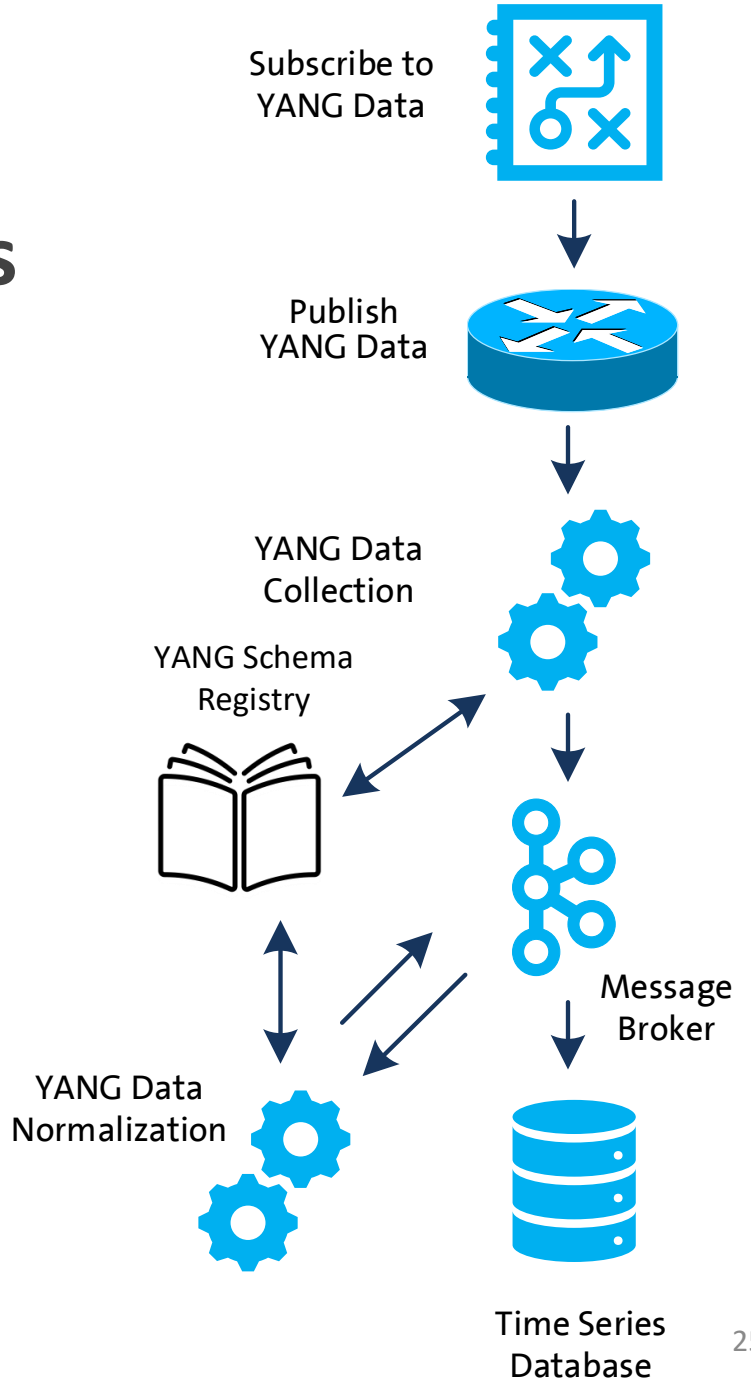
with on-change sync-on-start

- For alert use cases the hardware state notifications.


Yang
Kafka

Validate Configured Subscription YANG-Push Publisher Implementations

IETF 123 Hackathon, July 19-20th 2025

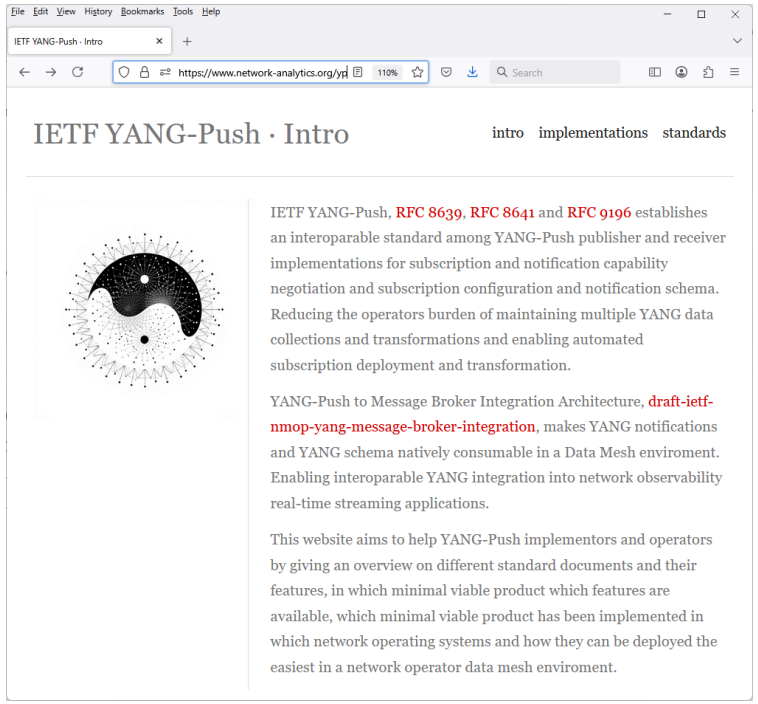


IETF 123 Hackathon

Test and Development Plan and Software

Test Plan

- **Subscription automation**
  - Discover YANG-Push systems and notifications capabilities and configure periodical and on-change subscriptions with netconf.
- **Notification integration**
  - Validate subscription state change and push-update and push-change-update notifications against schema with yanglint
  - Validate draft-ietf-nmop-message-broker-telemetry-message for draft-ietf-nmop-yang-message-broker-integration integration



Development Plan

- MVP 1 – Basic Requirements (9)
- MVP 2 – Scale and Secure (3)
- MVP 3 – Optimizations (2)

https://www.network-analytics.org/yp/how-to-deploy.html

Software

- YANG-Push Publisher - Cisco IOS XR
- YANG-Push Publisher - 6WIND VSR
- YANG-Push Publisher - Huawei NE (Router) and MA (OLT)
- YANG-Push Receiver – Netgauze
- udp-notif dissector - Wireshark

IETF 123 Hackathon

Repositories

Test Result Repository

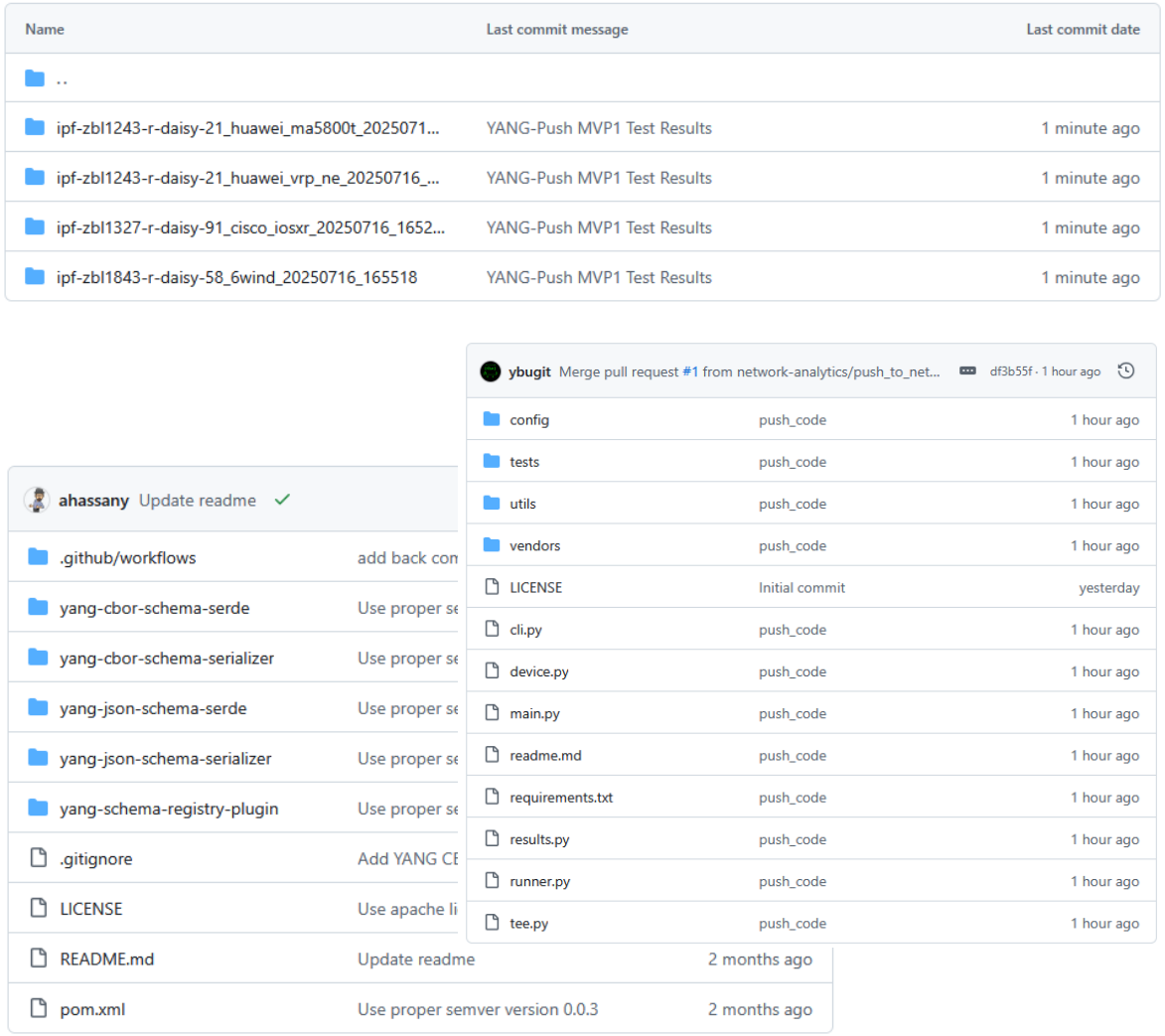
- https://github.com/network-analytics/ietf-network-analytics-document-status/tree/main/123/Hackathon
  - Packet capture on the wire
  - Netconf RPCs and YANG-Push JSON and CBOR encoded messages

Test Tool Repository

- https://github.com/network-analytics/yp_test
  - YANG-Push Test Automation Tool
  - Vendor deviations configuration

Apache Kafka Integration

- https://github.com/network-analytics/yang-kafka-integration
  - YANG Serializer
  - YANG Schema Registry Plugin



Name	Last commit message	Last commit date
..		
ipf-zbl1243-r-daisy-21_huawei_ma5800t_2025071...	YANG-Push MVP1 Test Results	1 minute ago
ipf-zbl1243-r-daisy-21_huawei_vrp_ne_20250716_...	YANG-Push MVP1 Test Results	1 minute ago
ipf-zbl1327-r-daisy-91_cisco_iosxr_20250716_1652...	YANG-Push MVP1 Test Results	1 minute ago
ipf-zbl1843-r-daisy-58_6wind_20250716_165518	YANG-Push MVP1 Test Results	1 minute ago

YANG-Push Implementation Status

IETF 123 – MVP 1

	6WIND VSR	Huawei NE	Huawei MA	Cisco IOS XR	Open-Source
RFC 8639 YANG-Push Subscription	✓	✓	✓	✓	
RFC 8641 YANG-Push Notification	✓	P	✓	✓	
draft-ietf-netconf-udp-notif	✓	✓	✓	✓	✓
draft-ietf-netconf-yang-notifications-versioning	✓	✓	✓	✓	
draft-tgraf-netconf-notif-sequencing	✓	✓	✓	✓	
draft-tgraf-netconf-yang-push-observation-time	✓	✓	✓	✓	
RFC 8525 YANG Library	✓	✓	✓	✓	
draft-ietf-netconf-yang-library-augmentation	✓	✓	✓	✓	✓
RFC 9196 System and Notification Capabilities			✓	P	
draft-ietf-netconf-notif-envelope	✓	✓	✓	✓	

NetGauze
Pmacct
udp-notif-c-collector
yang-library-augmentedby

Green marked describes new capability at IETF 123. "P" to partially implemented.

YANG Schema Tree

```
module: bbf-hardware-cpu

  augment /ietf-hardware:hardware/ietf-hardware:component:
    +--ro cpu-processor-data
       +--ro cpu-usage
       |  +--ro cpu-core-processes?   bbf-yang-types:percent
       |  +--ro cpu-user?             bbf-yang-types:percent
       |  +--ro cpu-idle?             bbf-yang-types:percent
       |  +--ro cpu-hwio?             bbf-yang-types:percent
       |  +--ro cpu-io?               bbf-yang-types:percent
       |  +--ro cpu-nice?             bbf-yang-types:percent
       |  +--ro cpu-swint?            bbf-yang-types:percent
       +--ro memory-usage
          +--ro used-mem?             uint64
          +--ro total-memory?         uint64
          +--ro free-memory?          uint64
          +--ro buffer-memory?        uint64
          +--ro total-swap-memory?    uint64
          +--ro used-swap?            uint64
          +--ro free-swap?            uint64
          +--ro available-mem?        uint64
```

Huawei VRP

YANG Semantics

```
container memory-usage {
        description
          "Statistics associated with memory utilization.";
        leaf total-memory {
          type uint64;
          units "kibibytes";
          description
            "The total amount of memory in kibibytes.";
        }
        leaf free-memory {
          type uint64;
          units "kibibytes";
          description
            "Total free memory in kibibytes.";
        }
```

YANG-Push Subscription Started


```
{
    "ietf-yp-notification:envelope": {
        "event-time": "2025-05-27T11:32:09.530+01:00",
        "hostname": "ipd-zbl1536-s-ah-79",
        "sequence-number": 0,
        "notification-contents": {
            "ietf-subscribed-notifications:subscription-started": {
                "id": 1,
                "ietf-yang-push:datastore": "ietf-datastores:operational",
                "ietf-yang-push:datastore-xpath-filter": "/ietf-
interfaces:interfaces/interface[type='iana-if-type:ethernetCsmacd']/statistics",
                "dscp": 0,
                "transport": "ietf-udp-notif-transport:udp-notif",
                "encoding": "ietf-subscribed-notifications:encode-json",
                "ietf-yang-push:periodic": {
                    "period": 6000
                },
                "ietf-yang-push-revision:module-version": [
                    {
                        "module-name": "iana-if-type",
                        "revision": "2017-01-19",
                        "revision-label": ""
                    },
```


YANG-Push Push Update


```
{
    "ietf-yp-notification:envelope": {
        "event-time": "2025-05-27T10:37:10.180+01:00",
        "hostname": "ipd-zbl1536-s-ah-79",
        "sequence-number": 0,
        "notification-contents": {
            "ietf-yang-push:push-update": {
                "id": 16,
                "ietf-yp-observation:timestamp": "2025-05-27T10:37:10.180+01:00",
                "ietf-yp-observation:point-in-time": "current-accounting",
                "ietf-distributed-notif:message-publisher-id": 3021116849,
                "datastore-contents": {
                    "ietf-hardware:hardware": {
                        "component": [
                            {
                                "name": "cpu.0.2",
                                "class": "iana-hardware:cpu",
                                "bbf-hardware-cpu:cpu-processor-data": {
                                    "cpu-usage": {
                                        "cpu-idle": 86
                                    },
                                    "memory-usage": {
                                        "total-memory": "1409024",
                                        "free-memory": "1067745"
                                    }
```

YANG Schema Tree

Cisco IOS XR

```
module: openconfig-lacp
  +--rw lacp
     +--rw config
     |  +--rw system-priority?   uint16
     +--ro state
     |  +--ro system-priority?   uint16
     +--rw interfaces
        +--rw interface* [name]
           +--rw name       -> ../config/name
           +--rw config
           |  +--rw name?              oc-if:base-interface-ref
           |  +--rw interval?          lacp-period-type
           |  +--rw lacp-mode?         lacp-activity-type
           |  +--rw system-id-mac?     oc-yang:mac-address
           |  +--rw system-priority?   uint16
           +--ro state
           |  +--ro name?              oc-if:base-interface-ref
           |  +--ro interval?          lacp-period-type
           |  +--ro lacp-mode?         lacp-activity-type
           |  +--ro system-id-mac?     oc-yang:mac-address
           |  +--ro system-priority?   uint16
```

YANG Semantics

```
 grouping aggregation-lacp-global-config {
    description
      "Configuration data for LACP aggregate interfaces";


    leaf system-priority {
      type uint16;
      description
        "Sytem priority used by the node on this LAG interface.
        Lower value is higher priority for determining which node
        is the controlling system.";
    }
  }
```

YANG-Push Subscription Started

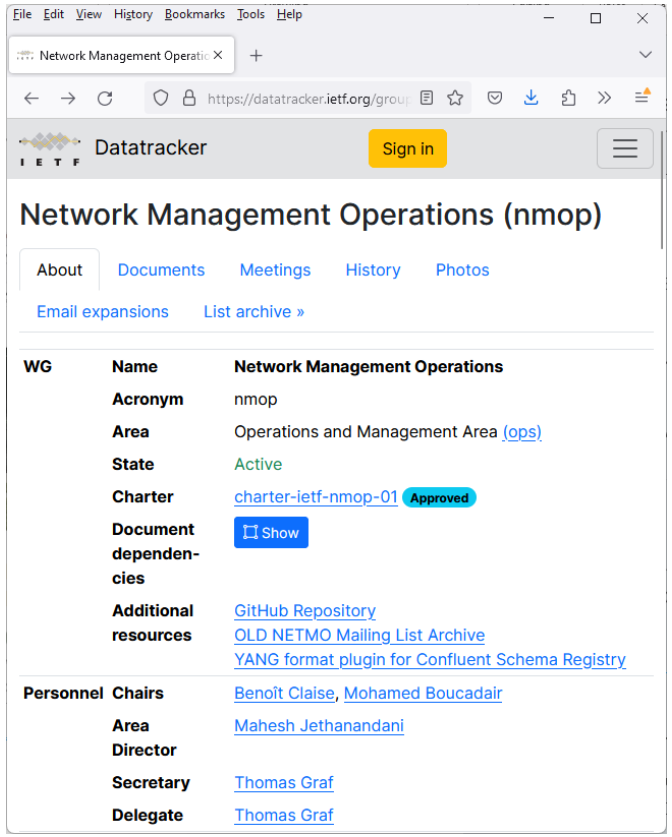

```
{
    "ietf-yp-notification:envelope": {
        "event-time": "2025-06-17T07:33:46.061Z",
        "hostname": "ipf-zbl1327-r-daisy-91",
        "sequence-number": 0,
        "contents": {
            "ietf-subscribed-notifications:subscription-started": {
                "id": 17,
                "ietf-yang-push:datastore": "operational",
                "ietf-yang-push:datastore-xpath-filter":
"openconfig-lacp:lacp/state",
                "transport": "ietf-udp-notif-transport:udp-notif",
                "ietf-yang-push-revision:module-version": [
                    {
                        "module-name": "openconfig-lacp",
                        "revision": "2023-12-11"
                    }
                ],
                "ietf-yang-push-revision:yang-library-content-id":
"4df70b4158a31ba6334f11b7bc2d41e6bbc0f16b",
                "encoding": "encode-json",
                "ietf-yang-push:on-change": {
                    "sync-on-start": true
                }
```


YANG-Push Push Update

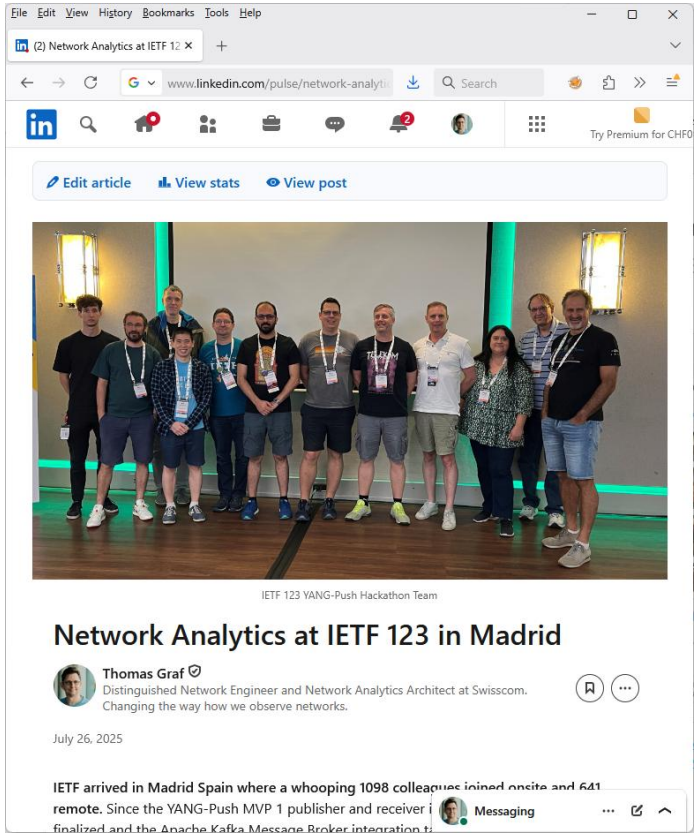

```
{
    "ietf-yp-notification:envelope": {
        "event-time": "2025-06-17T07:33:48.741Z",
        "hostname": "ipf-zbl1327-r-daisy-91",
        "sequence-number": 1,
        "contents": {
            "ietf-yang-push:push-update": {
                "id": 17,
                "ietf-yp-observation:timestamp": "2025-06-17T07:33:48.741Z",
                "ietf-yp-observation:point-in-time": "initial-state",
                "datastore-contents": {
                    "openconfig-lacp:lacp": {
                        "state": {
                            "system-priority": 32768
                        }
```

IETF NMOP 123 – Network Observability Development

Network Anomaly Detection and YANG-Push/Message Broker Integration



https://datatracker.ietf.org/group/nmop/about/



https://www.linkedin.com/pulse/network-analytics-ietf-123-madrid-thomas-graf-jjzge/

Extensible YANG model for YANG-Push Notifications

For XML, JSON or CBOR encoded messages with hostname, sequence-number and observation-time

```
notifications:
  +---n envelope
     +--ro event-time                    yang:date-and-time
     +--ro hostname?                     inet:host
     |       {notification-hostname-sequence-number}?
     +--ro sequence-number?              yang:counter32
     |       {notification-hostname-sequence-number}?
     +--ro notification-contents?        <anydata>

module: ietf-yp-observation-time
  augment /yp:push-update:
    +--ro observation-time?   yang:date-and-time
    +--ro point-in-time?      enumeration
  augment /yp:push-change-update:
    +--ro observation-time?   yang:date-and-time
    +--ro point-in-time?      enumeration
  augment /sysc:system-capabilities/notc:subscription-capabilities:
    +--ro yang-push-observation-supported?
            inotifseq:notification-support
            {yang-push-observation-timestamp}?
```

```
{
    "ietf-yp-notification:envelope": {
    "event-time": "2023-03-25T08:30:11.22Z",
    "hostname": "example-router",
    "sequence-number": 1,
    "notification-contents": {
      "ietf-yang-push:push-update": {
        "id": 6666,
        "ietf-yp-observation-time:observation-time": "2023-02-04T16:30:09.44Z",
        "ietf-yp-observation-time:point-in-time": "current-accounting",
        "datastore-contents": {
          "ietf-interfaces:interfaces": [
            {
              "interface": {
                "name": "eth0",
                "type": "iana-if-type:ethernetCsmacd",
                "oper-status": "up",
                "mtu": 1500
```

- draft-ietf-netconf-notif-envelope defines new extensible notification structure, defined in YANG, for use in YANG-Push Notification messages enabling any YANG compatible encodings such as XML RFC 7950, JSON RFC 7951 or CBOR RFC 9264.
- New notification envelope can be enabled in "ietf-subscribed-notification" RFC 8639.
- Capability can be discovered through 'ietf-notification-capabilities' RFC 9196.
- Supports the following notification metadata extensions
  - **hostname:** Describes the node's hostname according to the 'sysName' object definition in RFC 1213 from where the message was published from. This value is usually configured on the node by the administrator to uniquely identify the node in the network.
  - **sequence-number:** Generates a unique sequence number for each published message by the publisher process. The number counts up at every published notification message as described in RFC 9187.
  - **observation-time:** Describes the measurement observation time for the "push-update" notification in a "periodical" and for the "push-change-update" notification in a "on-change" subscription.
  - **point-in-time:** Describes at which point in time the value of observation-time was observed.

Support of Versioning in YANG Notifications Subscription

For subscription state change notification messages

```
module: ietf-yang-push-revision
  augment /sn:establish-subscription/sn:input:
    +---w module-version-config* [module-name]
       +---w module-name       yang:yang-identifier
       +---w revision?         rev:revision-date-or-label
       +---w revision-label?   ysver:version

 augment /sn:subscription-started:
    +--ro module-version* [module-name]
    |       {yang-push-revision-supported}?
    |  +--ro module-name       yang:yang-identifier
    |  +--ro revision          rev:revision-date
    |  +--ro revision-label?   ysver:version
    +--ro yang-library-content-id?       -> /yanglib:yang-library/content-id
            {yang-push-revision-supported}?
```

```
{
    "ietf-notification:notification": {
      "eventTime": "2023-03-25T08:30:11.22Z",
      "ietf-notification-sequencing:sysName": "example-router",
      "ietf-notification-sequencing:sequenceNumber": 1,
      "ietf-subscribed-notification:subscription-started": {
        "id": 6666,
        "ietf-yang-push:datastore": "ietf-datastores:operational",
        "ietf-yang-push:datastore-xpath-filter": "/if:interfaces",
        "ietf-yang-push-revision:revision": "2014-05-08",
        "ietf-yang-push-revision:module-name": "ietf-interfaces",
        "ietf-yang-push-revision:revision-label": "",,
        "ietf-yang-push-revision:yang-library-content-id": "1",
        "ietf-distributed-notif:message-observation-domain-id": [1,2],
        "transport": "ietf-udp-notif-transport:udp-notif",
        "encoding": "encode-json",
        "ietf-yang-push:periodic": {
          "ietf-yang-push:period": 100
        }
      }
    }
  }
```

- **Network operators need to control semantics in its data processing pipeline. That includes YANG-Push.**
- This is today only possible during YANG-Push subscription but not when nodes are being upgraded or when messages are being published for configured subscription.
- draft-ietf-netconf-yang-notifications-versioning extends the YANG push subscription and publishing mechanism defined in RFC 8641:
  - **By adding the ability to subscribe to a specific revision** or latest-compatible-semversion of one or more yang modules.
  - **By extending the YANG push Subscription State Change Notifications Message** so that the YANG push receiver learns beside the xpath and the sub-tree filter also the yang module name, revision, revision-label and the yang-library-content-id.

    With YANG Library content-id a YANG-Push receiver is now able to detect changes in the YANG library. This includes also the imported YANG modules of the subscribed xpath.

- Extends RFC 9196 defined subscription-capabilities with a **yang-push-module-revision-supported** leaf.

YANG Notification Transport Capabilities

Extending System Capabilities for YANG-Push Configured Subscription Transport

```
module: ietf-notification-transport-capabilities

  augment /sysc:system-capabilities/notc:subscription-capabilities:
    +--ro transport-capabilities
       +--ro transport-capability* [transport-protocol]
          +--ro transport-protocol    identityref
          +--ro security-protocol?    identityref
          +--ro encoding-format*      identityref
```

```
augment "/sysc:system-capabilities/notc:subscription-capabilities" {
    description "Add system level capability.";
    container transport-capabilities {
      description "Capabilities related to YANG-Push transports.";
      list transport-capability {
        key "transport-protocol";
        description "Capability list related to notification transport capabilities.";
        leaf transport-protocol {
          type identityref {
            base sn:transport;
          }
          description "Supported transport protocol for YANG-Push.";
        }
        leaf security-protocol {
          type identityref {
            base security-protocol;
          }
          description "Type of secure transport.";
        }
        leaf-list encoding-format {
          type identityref {
            base sn:encoding;
          }
          description "Supported encoding formats.";
        }
      }
    }
```

- draft-ietf-netconf-yp-transport-capabilities augments System Capabilities model and provides additional transport related attributes associated with system capabilities:
  - Specification of transport protocols the client can request to establish a draft-ietf-netconf-udp-notif or draft-ietf-netconf-https-notif configured transport connection;
  - Specification of transport encoding, such as JSON or XML as defined in RFC 8040 or CBOR as defined in RFC 9254 the client can request to encode YANG notifications;
  - Specification of secure transport mechanisms that are needed by the client to communicate with the server such as DTLS as defined in RFC 9147 TLS as defined in RFC 8446 or SSH as defined in RFC 4254;

Augmented-by Addition

YANG Library Extension

```
module: ietf-yang-library
  +--ro yang-library
  |  +--ro module-set* [name]
  |  |  +--ro name                    string
  |  |  +--ro module* [name]
  |  |  |  +--ro name                          yang:yang-identifier
  |  |  |  +--ro revision?                     revision-identifier
  |  |  |  +--ro namespace                     inet:uri
  |  |  |  +--ro location*                     inet:uri
  |  |  |  +--ro submodule* [name]
  |  |  |  |  +--ro name         yang:yang-identifier
  |  |  |  |  +--ro revision?    revision-identifier
  |  |  |  |  +--ro location*    inet:uri
  |  |  |  +--ro feature*                      yang:yang-identifier
  |  |  |  +--ro deviation*                    -> ../../module/name
  |  |  |  +--ro yanglib-aug:augmented-by*
                                     -> ../../yanglib:module/name
```

- With YANG-Push xpath or sub-tree a part of the YANG-Push data tree is subscribed.
- With YANG Library the relationship among the subscribed YANG modules can be determined from the top of the YANG tree. **What is missing is the ability to discover dependencies within the YANG tree**.
- draft-ietf-netconf-yang-library-augmentedby extends the YANG library defined in RFC 8525:
  - **By adding augmented-by YANG module relation**.

Validate anydata schema subtree with YANG Library

RFC 7950 Extension

```
notifications:
    +---n push-update
    |  +--ro id?                      sn:subscription-id
    |  +--ro datastore-contents?      <anydata>
```

```
{
  "ietf-yang-push:push-update": {
    "id": 89,
    "datastore-contents": {
      "ietf-interfaces:interfaces": {
      "interface": [
        {
          "name": "eth0",
          "oper-status": "down"
        }]
      }}
  }
}
```

- With YANG-Push xpath or sub-tree a part of the YANG-Push data tree is subscribed. The subscribed YANG datastore content is published as anydata, event though the content has a valid schema.
- RFC 7950 lacks specification how the data model of anydata content is exposed through YANG library defined in RFC 8525.
- draft-aelhassany-anydata-validation extends RFC 7950 by describing:
  - **How anydata can be validated with YANG Library.**

RFC 7950

7.10. The "anydata" Statement

The "anydata" statement defines an interior node in the schema tree. It takes one argument, which is an identifier, followed by a block of substatements that holds detailed anydata information.

The "anydata" statement is used to represent an unknown set of nodes that can be modeled with YANG, except anyxml, but for which the data model is not known at module design time. It is possible, though not required, for the data model for anydata content to become known through protocol signaling or other means that are outside the scope of this document.

YANG-Push Operational Data Observability Enhancements

Simplifies by combining periodic and on-change subscription

```
module: ietf-yp-ext

  augment /sn:subscription-started/yp:update-trigger:
    +--:(periodic-and-on-change) {yp:on-change}?
       +-- periodic-and-on-change!
          +-- period               yp:centiseconds
          +-- anchor-time?         yang:date-and-time
          +-- dampening-period?    yp:centiseconds
          +-- sync-on-start?       boolean
          +-- excluded-change*     yp:change-type
  augment /sn:subscription-started:
    +--ro common-notification-format?   boolean
  augment /sn:subscription-modified/yp:update-trigger:
    +--:(periodic-and-on-change) {yp:on-change}?
       +-- periodic-and-on-change!
          +-- period               yp:centiseconds
          +-- anchor-time?         yang:date-and-time
          +-- dampening-period?    yp:centiseconds
          +-- sync-on-start?       boolean
          +-- excluded-change*     yp:change-type
  augment /sn:subscription-modified:
    +--ro common-notification-format?   boolean
  augment /sn:subscriptions/sn:subscription/yp:update-trigger:
    +--:(periodic-and-on-change) {yp:on-change}?
       +--rw periodic-and-on-change!
          +--rw period               yp:centiseconds
          +--rw anchor-time?         yang:date-and-time
          +--rw dampening-period?    yp:centiseconds
          +--rw sync-on-start?       boolean
          +--rw excluded-change*     yp:change-type
  augment /sn:subscriptions/sn:subscription:
    +--rw common-notification-format?   boolean
```

- To reduce complexities in modelling the operational state, the following two YANG-Push enhancements are proposed:
  - A new YANG-Push encoding format that can be used for both on-change and periodic subscriptions that reports the data from the subscription filter point.
  - A combined periodic and on-change subscription that reports events on a periodical cadence and also if changes to the data have occurred.

```
notifications:
  +---n update
     +--ro id?                    sn:subscription-id
     +--ro subscription-path?     yang:xpath1.0
     +--ro target-path?           string
     +--ro snapshot-type?         enumeration
     +--ro observation-time?      yang:date-and-time
     +--ro datastore-snapshot?    <anydata>
     +--ro incomplete?            empty
```

- This removes the YANG Patch format RFC 8072 dependency and eases the message broker integration.
- Allows the YANG-Push publisher to split a subscription into smaller child subscriptions for more efficient independent and concurrent processing. Reuses the ideas from draft-ietf-netconf-distributed-notif. Child subscriptions remain encoded from the same subscription point.

RFC 8343 – ietf-interfaces.yang vs. openconfig-interfaces.yang

YANG Data Model for Interface Management

```
module: ietf-interfaces
  +--rw interfaces
     +--rw interface* [name]
        +--rw name                            string
        +--rw description?                    string
        +--rw type                            identityref
        +--rw enabled?                        boolean
        +--rw link-up-down-trap-enable?       enumeration {if-mib}?
        +--ro admin-status                    enumeration {if-mib}?
        +--ro oper-status                     enumeration
        +--ro last-change?                    yang:date-and-time
        +--ro if-index                        int32 {if-mib}?
        +--ro phys-address?                   yang:phys-address
        +--ro higher-layer-if*                interface-ref
        +--ro lower-layer-if*                 interface-ref
        +--ro speed?                          yang:gauge64
        +--ro statistics
           +--ro discontinuity-time     yang:date-and-time
           +--ro in-octets?             yang:counter64
           +--ro in-unicast-pkts?       yang:counter64
           +--ro in-broadcast-pkts?     yang:counter64
           +--ro in-multicast-pkts?     yang:counter64
           +--ro in-discards?           yang:counter32
           +--ro in-errors?             yang:counter32
           +--ro in-unknown-protos?     yang:counter32
           +--ro out-octets?            yang:counter64
           +--ro out-unicast-pkts?      yang:counter64
           +--ro out-broadcast-pkts?    yang:counter64
           +--ro out-multicast-pkts?    yang:counter64
           +--ro out-discards?          yang:counter32
           +--ro out-errors?            yang:counter32
```

```
module: openconfig-interfaces
  +--rw interfaces
     +--rw interface* [name]
        +--rw name             -> ../config/name
        +--rw config
        |  +--rw name?            string
        |  +--rw type             identityref
        |  +--rw mtu?             uint16
        |  +--rw loopback-mode?   oc-opt-types:loopback-mode-type
        |  +--rw description?     string
        |  +--rw enabled?         boolean
        +--ro state
        |  +--ro name?            string
        |  +--ro type             identityref
        |  +--ro mtu?             uint16
        |  +--ro loopback-mode?   oc-opt-types:loopback-mode-type
        |  +--ro description?     string
        |  +--ro enabled?         boolean
        |  +--ro ifindex?         uint32
        |  +--ro admin-status     enumeration
        |  +--ro oper-status      enumeration
        |  +--ro last-change?     oc-types:timeticks64
        |  +--ro logical?         boolean
        |  +--ro management?      boolean
        |  +--ro cpu?             boolean
        |  +--ro counters
        |     +--ro in-octets?             oc-yang:counter64
        |     +--ro in-pkts?               oc-yang:counter64
        |     +--ro in-unicast-pkts?       oc-yang:counter64
        |     +--ro in-broadcast-pkts?     oc-yang:counter64
        |     +--ro in-multicast-pkts?     oc-yang:counter64
        |     +--ro in-discards?           oc-yang:counter64
        |     +--ro in-errors?             oc-yang:counter64
        |     +--ro in-unknown-protos?     oc-yang:counter64
        |     +--ro in-fcs-errors?         oc-yang:counter64
        |     +--ro out-octets?            oc-yang:counter64
        |     +--ro out-pkts?              oc-yang:counter64
        |     +--ro out-unicast-pkts?      oc-yang:counter64
        |     +--ro out-broadcast-pkts?    oc-yang:counter64
        |     +--ro out-multicast-pkts?    oc-yang:counter64
        |     +--ro out-discards?          oc-yang:counter64
        |     +--ro out-errors?            oc-yang:counter64
```

```
module: openconfig-interfaces
  +--rw interfaces
     +--rw interface* [name]
     +--rw subinterfaces
        +--rw subinterface* [index]
           +--rw index     -> ../config/index
           +--rw config
           |  +--rw index?         uint32
           |  +--rw description?   string
           |  +--rw enabled?       boolean
           +--ro state
              +--ro index?          uint32
              +--ro description?    string
              +--ro enabled?        boolean
              +--ro name?           string
              +--ro ifindex?        uint32
              +--ro admin-status    enumeration
              +--ro oper-status     enumeration
              +--ro last-change?    oc-types:timeticks64
              +--ro logical?        boolean
              +--ro management?     boolean
              +--ro cpu?            boolean
              +--ro counters
                 +--ro in-octets?             oc-yang:counter64
                 +--ro in-pkts?               oc-yang:counter64
                 +--ro in-unicast-pkts?       oc-yang:counter64
                 +--ro in-broadcast-pkts?     oc-yang:counter64
                 +--ro in-multicast-pkts?     oc-yang:counter64
                 +--ro in-discards?           oc-yang:counter64
                 +--ro in-errors?             oc-yang:counter64
                 +--ro in-unknown-protos?     oc-yang:counter64
                 +--ro in-fcs-errors?         oc-yang:counter64
                 +--ro out-octets?            oc-yang:counter64
                 +--ro out-pkts?              oc-yang:counter64
                 +--ro out-unicast-pkts?      oc-yang:counter64
                 +--ro out-broadcast-pkts?    oc-yang:counter64
                 +--ro out-multicast-pkts?    oc-yang:counter64
                 +--ro out-discards?          oc-yang:counter64
                 +--ro out-errors?            oc-yang:counter64
```

RFC 8348 – ietf-hardware.yang vs. openconfig-platform.yang

YANG Data Model for Hardware Management

```
module: ietf-hardware
  +--rw hardware
     +--ro last-change?   yang:date-and-time
     +--rw component* [name]
        +--rw name                    string
        +--rw class                   identityref
        +--ro physical-index?         int32 {entity-mib}?
        +--ro description?            string
        +--rw parent?                 -> ../../component/name
        +--rw parent-rel-pos?         int32
        +--ro contains-child*         -> ../../component/name
        +--ro hardware-rev?           string
        +--ro firmware-rev?           string
        +--ro software-rev?           string
        +--ro serial-num?             string
        +--ro mfg-name?               string
        +--ro model-name?             string
        +--rw alias?                  string
        +--rw asset-id?               string
        +--ro is-fru?                 boolean
        +--ro mfg-date?               yang:date-and-time
        +--rw uri*                    inet:uri
        +--ro uuid?                   yang:uuid
        +--rw state {hardware-state}?
        |  +--ro state-last-changed?   yang:date-and-time
        |  +--rw admin-state?          admin-state
        |  +--ro oper-state?           oper-state
        |  +--ro usage-state?          usage-state
        |  +--ro alarm-state?          alarm-state
        |  +--ro standby-state?        standby-state
        +--ro sensor-data {hardware-sensor}?
           +--ro value?                sensor-value
           +--ro value-type?           sensor-value-type
           +--ro value-scale?          sensor-value-scale
           +--ro value-precision?      sensor-value-precision
           +--ro oper-status?          sensor-status
           +--ro units-display?        string
           +--ro value-timestamp?      yang:date-and-time
           +--ro value-update-rate?    uint32
```

```
module: openconfig-platform
  +--rw components
     +--rw component* [name]
        +--rw name                              -> ../config/name
        +--rw config
        |  +--rw name?   string
        +--ro state
        |  +--ro name?                          string
        |  +--ro type?                          union
        |  x--ro id?                            string
        |  x--ro location?                      string
        |  +--ro install-position?              string
        |  +--ro install-component?             -> ../name
        |  +--ro description?                   string
        |  +--ro mfg-name?                      string
        |  +--ro mfg-date?                      oc-yang:date
        |  +--ro hardware-version?              string
        |  +--ro firmware-version?              string
        |  +--ro software-version?              string
        |  +--ro serial-no?                     string
        |  +--ro part-no?                       string
        |  +--ro model-name                     string
        |  +--ro clei-code?                     string
        |  +--ro removable?                     boolean
        |  +--ro oper-status?                   identityref
        |  +--ro empty?                         boolean
        |  +--ro parent?                        -> ../../../component/config/name
        |  +--ro redundant-role?                oc-platform-types:component-redundant-role
        |  +--ro last-poweroff-reason
        |  |  +--ro trigger?   component-last-poweroff-reason-trigger
        |  |  +--ro details?   string
        |  +--ro last-poweroff-time?            oc-types:timeticks64
        |  +--ro last-switchover-reason
        |  |  +--ro trigger?   component-redundant-role-switchover-reason-trigger
        |  |  +--ro details?   string
        |  +--ro last-switchover-time?          oc-types:timeticks64
        |  +--ro last-reboot-reason?            identityref
        |  x--ro last-reboot-time?              oc-types:timeticks64
        |  +--ro boot-time?                     oc-types:timeticks64
        |  +--ro switchover-ready?              boolean
        |  +--ro base-mac-address?              oc-yang:mac-address
        |  +--ro temperature
        |  |  +--ro instant?            decimal64
        |  |  +--ro avg?                decimal64
        |  |  +--ro min?                decimal64
        |  |  +--ro max?                decimal64
        |  |  +--ro alarm-status?       boolean
        |  |  +--ro alarm-threshold?    uint32
        |  |  +--ro alarm-severity?     identityref
        |  +--ro memory
        |  |  +--ro available?   uint64
        |  |  +--ro utilized?    uint64
        |  +--ro allocated-power?               uint32
        |  +--ro used-power?                    Uint32
        +--rw chassis
        |  +--rw config
        |  +--ro state
        |  +--rw utilization
        |     +--rw resources
        |        +--rw resource* [name]
        |           +--rw name      -> ../config/name
        |           +--rw config
        |           |  +--rw name?                        string
        |           |  +--rw used-threshold-upper?        oc-types:percentage
        |           |  +--rw used-threshold-upper-clear?  oc-types:percentage
        |           +--ro state
        |              +--ro name?                        string
        |              +--ro used-threshold-upper?        oc-types:percentage
        |              +--ro used-threshold-upper-clear?  oc-types:percentage
        |              +--ro used?                        uint64
        |              +--ro committed?                   uint64
        |              +--ro free?                        uint64
        |              +--ro max-limit?                   uint64
        |              +--ro high-watermark?              uint64
        |              +--ro last-high-watermark?         oc-types:timeticks64
        |              +--ro used-threshold-upper-exceeded?  boolean
        +--rw power-supply
        |  +--rw config
        |  +--ro state
        +--rw fan
        |  +--rw config
        |  +--ro state
        |     +--ro oc-fan:speed?   uint32
        +--rw fabric
        |  +--rw config
        |  +--ro state
        +--rw storage
        |  +--rw config
        |  +--ro state
        +--rw cpu
        |  +--rw config
        |  +--ro state
        |  +--rw oc-cpu:utilization
        |     +--ro oc-cpu:state
        +--rw integrated-circuit
        |  +--rw config
        |  +--ro state
        |  +--rw utilization
        |     +--rw resources
        |        +--rw resource* [name]
        |           +--rw name      -> ../config/name
        |           +--rw config
        |           |  +--rw name?                        string
        |           |  +--rw used-threshold-upper?        oc-types:percentage
        |           |  +--rw used-threshold-upper-clear?  oc-types:percentage
        |           +--ro state
        |              +--ro name?                        string
        |              +--ro used-threshold-upper?        oc-types:percentage
        |              +--ro used-threshold-upper-clear?  oc-types:percentage
        |              +--ro used?                        uint64
        |              +--ro committed?                   uint64
        |              +--ro free?                        uint64
        |              +--ro max-limit?                   uint64
        |              +--ro high-watermark?              uint64
        |              +--ro last-high-watermark?         oc-types:timeticks64
        |              +--ro used-threshold-upper-exceeded?  boolean
        +--rw oc-transceiver:transceiver
        |  +--rw oc-transceiver:config
        |  |  +--rw oc-transceiver:enabled?                boolean
        |  |  +--rw oc-transceiver:form-factor-preconf?    identityref
        |  |  +--rw oc-transceiver:ethernet-pmd-preconf?   identityref
        |  |  +--rw oc-transceiver:fec-mode?               identityref
        |  |  +--rw oc-transceiver:module-functional-type? identityref
        |  +--ro oc-transceiver:state
        |  |  +--ro oc-transceiver:enabled?                boolean
        |  |  +--ro oc-transceiver:form-factor-preconf?    identityref
        |  |  +--ro oc-transceiver:ethernet-pmd-preconf?   identityref
        |  |  +--ro oc-transceiver:fec-mode?               identityref
        |  |  +--ro oc-transceiver:module-functional-type? identityref
        |  |  +--ro oc-transceiver:present?                enumeration
        |  |  +--ro oc-transceiver:form-factor?            identityref
        |  |  +--ro oc-transceiver:connector-type?         identityref
        |  |  +--ro oc-transceiver:vendor?                 string
        |  |  +--ro oc-transceiver:vendor-part?            string
        |  |  +--ro oc-transceiver:vendor-rev?             string
        |  |  +--ro oc-transceiver:ethernet-pmd?           identityref
        |  |  +--ro oc-transceiver:sonet-sdh-compliance-code?  identityref
        |  |  +--ro oc-transceiver:otn-compliance-code?    identityref
        |  |  +--ro oc-transceiver:serial-no?              string
        |  |  +--ro oc-transceiver:date-code?              oc-yang:date-and-time
        |  |  +--ro oc-transceiver:fault-condition?        boolean
        |  |  +--ro oc-transceiver:fec-status?             identityref
        |  |  +--ro oc-transceiver:fec-uncorrectable-blocks?   yang:counter64
        |  |  +--ro oc-transceiver:fec-uncorrectable-words?    yang:counter64
        |  |  +--ro oc-transceiver:fec-corrected-bytes?        yang:counter64
        |  |  +--ro oc-transceiver:fec-corrected-bits?         yang:counter64
```

RFC 8632/8348 – ietf-alarms/ietf-hardware.yang vs openconfig-alarms.yang

YANG Data Model for Alarm Management

```
  notifications:
    +---n hardware-state-change
    +---n hardware-state-oper-enabled {hardware-state}?
    |  +--ro name?          -> /hardware/component/name
    |  +--ro admin-state?   -> /hardware/component/state/admin-state
    |  +--ro alarm-state?   -> /hardware/component/state/alarm-state
    +---n hardware-state-oper-disabled {hardware-state}?
       +--ro name?          -> /hardware/component/name
       +--ro admin-state?   -> /hardware/component/state/admin-state
       +--ro alarm-state?   -> /hardware/component/state/alarm-state
```

```
 notifications:
    +---n alarm-notification
    |  +--ro resource                resource
    |  +--ro alarm-type-id           alarm-type-id
    |  +--ro alarm-type-qualifier?   alarm-type-qualifier
    |  +--ro alt-resource*           resource
    |  +--ro related-alarm* [resource alarm-type-id alarm-type-
qualifier] {alarm-correlation}?
    |  |  +--ro resource                -> /alarms/alarm-
list/alarm/resource
    |  |  +--ro alarm-type-id           -> /alarms/alarm-
list/alarm[resource=current()/../resource]/alarm-type-id
    |  |  +--ro alarm-type-qualifier    -> /alarms/alarm-
list/alarm[resource=current()/../resource][alarm-type-
id=current()/../alarm-type-id]/alarm-type-qualifier
    |  +--ro impacted-resource*      resource {service-impact-
analysis}?
    |  +--ro root-cause-resource*    resource {root-cause-analysis}?
    |  +--ro time                    yang:date-and-time
    |  +--ro perceived-severity      severity-with-clear
    |  +--ro alarm-text              alarm-text
    +---n alarm-inventory-changed
```

```
module: openconfig-platform
  +--rw components
     +--rw component* [name]
        +--rw name                    -> ../config/name
        +--rw config
        |  +--rw name?   string
        +--ro state
        |  +--ro oc-alarms:equipment-failure?    boolean
        |  +--ro oc-alarms:equipment-mismatch?   boolean
```

IEEE LLDP – ieee802-dot1ab-lldp.yang vs. openconfig-lldp.yang

YANG Data Model for LLDP Neighbor Discovery

```
module: ieee802-dot1ab-lldp
  +--rw lldp
     +--ro local-system-data
     |  +--ro chassis-id-subtype?                ieee:chassis-id-subtype-type
     |  +--ro chassis-id?                        ieee:chassis-id-type
     |  +--ro system-name?                       string
     |  +--ro system-description?                string
     |  +--ro system-capabilities-supported?     lldp-types:system-capabilities-map
     |  +--ro system-capabilities-enabled?       lldp-types:system-capabilities-map
     +--rw port* [name dest-mac-address]
        +--rw name                             if:interface-ref
        +--rw dest-mac-address                 ieee:mac-address
        +--ro port-id?                         ieee:port-id-type
        +--ro remote-systems-data* [time-mark remote-index]
           +--ro time-mark                           yang:timeticks
           +--ro remote-index                        uint32
           +--ro remote-too-many-neighbors?          boolean
           +--ro remote-changes?                     boolean
           +--ro chassis-id-subtype?                 ieee:chassis-id-subtype-type
           +--ro chassis-id?                         ieee:chassis-id-type
           +--ro port-id-subtype?                    ieee:port-id-subtype-type
           +--ro port-id?                            ieee:port-id-type
           +--ro port-desc?                          string
           +--ro system-name?                        string
           +--ro system-description?                 string
           +--ro system-capabilities-supported?      lldp-types:system-capabilities-map
           +--ro system-capabilities-enabled?        lldp-types:system-capabilities-map
```

```
module: openconfig-lldp
  +--rw lldp
     +--ro state
     |  +--ro enabled?                       boolean
     |  +--ro hello-timer?                   uint64
     |  +--ro suppress-tlv-advertisement*    identityref
     |  +--ro system-name?                   string
     |  +--ro system-description?            string
     |  +--ro chassis-id?                    string
     |  +--ro chassis-id-type?               oc-lldp-types:chassis-id-type
     +--rw interfaces
        +--rw interface* [name]
           +--rw name          -> ../config/name
           +--ro state
           |  +--ro name?       oc-if:base-interface-ref
           |  +--ro enabled?    boolean
           +--ro neighbors
              +--ro neighbor* [id]
                 +--ro id               -> ../state/id
                 +--ro state
                    |  +--ro system-name?               string
                    |  +--ro system-description?        string
                    |  +--ro chassis-id?                string
                    |  +--ro chassis-id-type?           oc-lldp-types:chassis-id-type
                    |  +--ro id?                        string
                    |  +--ro age?                       uint64
                    |  +--ro last-update?               int64
                    |  +--ro ttl?                       uint16
                    |  +--ro port-id?                   string
                    |  +--ro port-id-type?              oc-lldp-types:port-id-type
                    |  +--ro port-description?          string
                    |  +--ro management-address?        string
                    |  +--ro management-address-type?   string
```

IEEE dot1ax – ieee802-dot1ax.yang vs. openconfig-lacp.yang

YANG Data Model for LAG Interface Management

```
module: ieee802-dot1ax
  +--rw lag-system
     +--rw aggregating-system* [agg-system]
        +--rw agg-system          string
        +--rw system-id?          ieee:mac-address
        +--rw system-priority?    uint32

  augment /if:interfaces/if:interface:
    +--rw aggregator
       +--rw name?                           string
       +--rw agg-system-name?                string
       +--rw admin-state?                    enumeration
       +--rw link-up-down-notification?      enumeration
       +--rw collector-max-delay?            int16
       +--rw aggregator-lacp
          +--rw actor-admin-key?    int16

  augment /if:interfaces/if:interface:
    +--rw aggregation-port
       +--rw aggregation-port-lacp
          +--rw actor-system-priority?           int16
          +--rw actor-admin-key?                 int16
          +--rw partner-admin-system-priority?   int16
          +--rw partner-admin-system-id?         ieee:mac-address
          +--rw partner-admin-key?               int16
          +--rw actor-port-priority?             int16
          +--rw partner-admin-port?              int16
          +--rw partner-admin-port-priority?     int16
          +--rw actor-admin-state?               bits
          +--rw partner-admin-state?             bits
```

```
module: openconfig-lacp
  +--rw lacp
     +--ro state
     |  +--ro system-priority?   uint16
     +--rw interfaces
        +--rw interface* [name]
           +--rw name       -> ../config/name
           +--ro state
           |  +--ro name?              oc-if:base-interface-ref
           |  +--ro interval?          lacp-period-type
           |  +--ro lacp-mode?         lacp-activity-type
           |  +--ro system-id-mac?     oc-yang:mac-address
           |  +--ro system-priority?   uint16
           +--ro members
              +--ro member* [interface]
                 +--ro interface    -> ../state/interface
                 +--ro state
                    +--ro interface?          oc-if:base-interface-ref
                    +--ro activity?           lacp-activity-type
                    +--ro timeout?            lacp-timeout-type
                    +--ro synchronization?    lacp-synchronization-type
                    +--ro aggregatable?       boolean
                    +--ro collecting?         boolean
                    +--ro distributing?       boolean
                    +--ro system-id?          oc-yang:mac-address
                    +--ro oper-key?           uint16
                    +--ro partner-id?         oc-yang:mac-address
                    +--ro partner-key?        uint16
                    +--ro port-num?           uint16
                    +--ro partner-port-num?   uint16
                    +--ro last-change?        oc-types:timeticks64
```

RFC 9127 – ietf-bfd.yang vs. openconfig-bfd.yang

YANG Data Model for Bidirectional Forwarding Detection

BFD IP Single-Hop Hierarchy

https://datatracker.ietf.org/doc/html/rfc9127#section-2.6

```
  notifications:
    +---n singlehop-notification
       +--ro local-discr?                    discriminator
       +--ro remote-discr?                   discriminator
       +--ro new-state?                      state
       +--ro state-change-reason?            iana-bfd-types:diagnostic
       +--ro time-of-last-state-change?      yang:date-and-time
       +--ro dest-addr?                      inet:ip-address
       +--ro source-addr?                    inet:ip-address
       +--ro session-index?                  uint32
       +--ro path-type?                      identityref
       +--ro interface?                      if:interface-ref
       +--ro echo-enabled?                   boolean
```

BFD-over-LAG Hierarchy

https://datatracker.ietf.org/doc/html/rfc9127#section-2

```
  notifications:
    +---n lag-notification
       +--ro local-discr?                    discriminator
       +--ro remote-discr?                   discriminator
       +--ro new-state?                      state
       +--ro state-change-reason?            iana-bfd-types:diagnostic
       +--ro time-of-last-state-change?      yang:date-and-time
       +--ro dest-addr?                      inet:ip-address
       +--ro source-addr?                    inet:ip-address
       +--ro session-index?                  uint32
       +--ro path-type?                      identityref
       +--ro lag-name?                       if:interface-ref
       +--ro member-link?                    if:interface-ref
```

```
module: openconfig-bfd
  +--rw bfd
     +--rw interfaces
        +--rw interface* [id]
           +--rw id                      -> ../config/id
           +--ro state
           |  +--ro id?                              string
           |  +--ro enabled?                         boolean
           |  +--ro local-address?                   oc-inet:ip-address
           |  +--ro desired-minimum-tx-interval?     uint32
           |  +--ro required-minimum-receive?        uint32
           |  +--ro detection-multiplier?            uint8
           |  +--ro enable-per-member-link?          boolean
           +--rw interface-ref
           |  +--ro state
           |     +--ro interface?      -> /oc-if:interfaces/interface/name
           |     +--ro subinterface?   -> /oc-if:interfaces/interface[oc-
if:name=current()/../interface]/subinterfaces/subinterface/index
           +--rw peers
              +--ro peer* [local-discriminator]
                 +--ro local-discriminator    -> ../state/local-discriminator
                 +--ro state
                    +--ro local-address?                      oc-inet:ip-address
                    +--ro remote-address?                     oc-inet:ip-address
                    +--ro subscribed-protocols*               identityref
                    +--ro session-state?                      bfd-session-state
                    +--ro remote-session-state?               bfd-session-state
                    +--ro last-failure-time?                  oc-types:timeticks64
                    +--ro failure-transitions?                uint64
                    +--ro local-discriminator?                string
                    +--ro remote-discriminator?               string
                    +--ro local-diagnostic-code?              bfd-diagnostic-code
                    +--ro remote-diagnostic-code?             bfd-diagnostic-code
                    +--ro remote-minimum-receive-interval?    uint32
                    +--ro demand-mode-requested?              boolean
                    +--ro remote-authentication-enabled?      boolean
                    +--ro remote-control-plane-independent?   boolean
```

RFC 9130 – ietf-isis.yang vs. openconfig-isis.yang

YANG Data Model for the IS-IS Protocol

```
  notifications:
    +---n database-overload
    |  +--ro routing-protocol-name?   -> /rt:routing/
    |  |                                 control-plane-protocols/
    |  |                                 control-plane-protocol/name
    |  +--ro isis-level?              level
    |  +--ro overload?                enumeration
    +---n if-state-change
    |  +--ro routing-protocol-name?   -> /rt:routing/
    |  |                                 control-plane-protocols/
    |  |                                 control-plane-protocol/name
    |  +--ro isis-level?              level
    |  +--ro interface-name?          if:interface-ref
    |  +--ro interface-level?         level
    |  +--ro extended-circuit-id?     extended-circuit-id
    |  +--ro state?                   if-state-type
    +---n adjacency-state-change
    |  +--ro routing-protocol-name?   -> /rt:routing/
    |  |                                 control-plane-protocols/
    |  |                                 control-plane-protocol/name
    |  +--ro isis-level?              level
    |  +--ro interface-name?          if:interface-ref
    |  +--ro interface-level?         level
    |  +--ro extended-circuit-id?     extended-circuit-id
    |  +--ro neighbor?                string
    |  +--ro neighbor-system-id?      system-id
    |  +--ro state?                   adj-state-type
    |  +--ro reason?                  string
```

```
module: openconfig-network-instance
  +--rw network-instances
     +--rw network-instance* [name]
        +--rw name                          -> ../config/name
        +--rw protocols
           +--rw protocol* [identifier name]
              +--rw isis
                 |  +--rw global
                 |  +--rw interfaces
                 |     +--rw interface* [interface-id]
                 |        +--rw interface-id        -> ../config/interface-id
                 |        +--rw levels
                 |           |  +--rw level* [level-number]
                 |           |     +--rw level-number            -> ../config/level-number
                 |           |     +--ro adjacencies
                 |           |     |  +--ro adjacency* [system-id]
                 |           |     |     +--ro system-id    -> ../state/system-id
                 |           |     |     +--ro state
                 |           |     |        +--ro system-id                      oc-isis-types:system-id
                 |           |     |        +--ro neighbor-ipv4-address?         oc-inet:ipv4-address
                 |           |     |        +--ro neighbor-ipv6-address?         oc-inet:ipv6-address
                 |           |     |        +--ro neighbor-snpa?                 oc-isis-types:snpa
                 |           |     |        +--ro local-extended-circuit-id?     oc-isis-types:extended-circuit-id
                 |           |     |        +--ro neighbor-extended-circuit-id?  oc-isis-types:extended-circuit-id
                 |           |     |        +--ro priority?                      uint8
                 |           |     |        +--ro dis-system-id?                 oc-isis-types:system-id
                 |           |     |        +--ro neighbor-circuit-type?         oc-isis-types:level-type
                 |           |     |        +--ro adjacency-type?                oc-isis-types:level-type
                 |           |     |        +--ro adjacency-state?               oc-isis-types:isis-interface-adj-state
                 |           |     |        +--ro up-timestamp?                  oc-types:timeticks64
                 |           |     |        +--ro multi-topology?                boolean
                 |           |     |        +--ro topology*                      identityref
                 |           |     |        +--ro restart-support?               boolean
                 |           |     |        +--ro restart-suppress?              boolean
                 |           |     |        +--ro restart-status?                boolean
                 |           |     |        +--ro area-address*                  oc-isis-types:area-address
                 |           |     |        +--ro nlpid*                         enumeration
```