



This Communication is part of a project that has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N°101069732

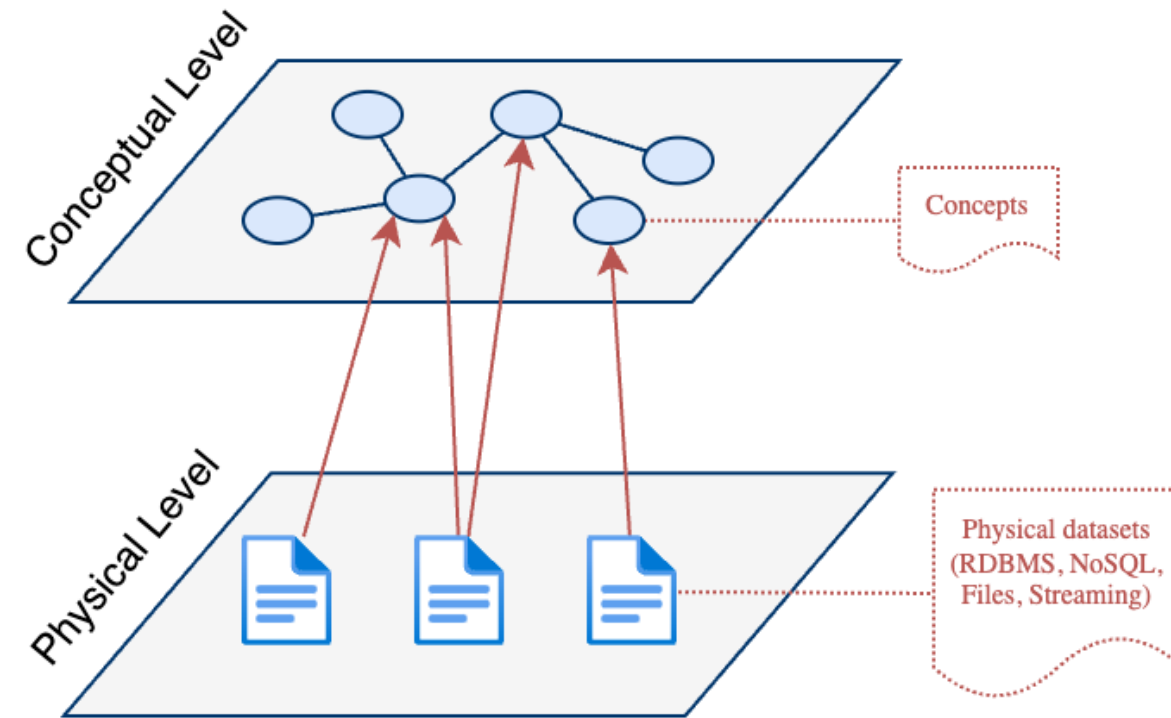


KNOWLEDGE GRAPHS FOR NETWORK MANAGEMENT

*IETF 118, NMRG 72nd meeting
11/10/2023*

Knowledge graphs and semantic interoperability

- **Semantic interoperability** for data heterogeneity [1] [2]:
 - Distributed data management at scale \square Data mesh [3]
 - Holistic access to integrated data \square Data fabric [4]
- The levels of data modelling [5] [6]:
 - Conceptual (information) level \square Business concepts
 - Physical level \square Technology-specific (e.g., YANG)
- Knowledge graphs to link the two levels:
 - Machine-readable representation of conceptual data models \square Ontologies
 - Self-defining \square Data travels with its meaning (semantic metadata)
 - Distributed in nature \square URIs for concepts and things



1. Network Telemetry Framework - <https://datatracker.ietf.org/doc/rfc9232/>
2. Research Challenges in Coupling Artificial Intelligence and Network Management - <https://datatracker.ietf.org/doc/draft-irtf-nmrg-ai-challenges/>
3. <https://github.com/network-analytics/draft-daisy-kafka-yang-integration/blob/main/draft-daisy-kafka-yang-integration-05.md>
4. Artificial Intelligence Framework for Network Management - <https://datatracker.ietf.org/doc/draft-pedro-nmrg-ai-framework/>
5. <https://piethein.medium.com/data-integration-and-data-modelling-demystified-ace6839f42a6>

Use Case: YANG Library (RFC 8525)

```
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 import-only-module* [name revision]
      | | | +--ro name      yang:yang-identifier
      | | | +--ro revision  union
      | | | +--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 schema* [name]
      | | +--ro name      string
      | | +--ro module-set* -> ../../module-set/name
      +--ro datastore* [name]
      | +--ro name      ds:datastore-ref
      | +--ro schema    -> ../../schema/name
      +--ro content-id  string
```

Concept "YANG Module"

The concept (class/entity) is the same.

The difference lies in the **relationship** with this concept \square implement vs import

Concept "YANG Submodule"

Use Case: Interface management modules

OpenConfig

```
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
```

```
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}?
```

IETF

Vendor Proprietary

```
module: huawei-ifm
  +--rw ifm
    +--rw global
      | +--rw statistic-interval?    uint32
      | +--rw ipv4-ignore-primary-sub? boolean
      | +--rw sub-interface-link-trap-enable? boolean
      | +--rw ipv4-conflict-enable!
      | | +--rw preempt-enable?    boolean
      | +--rw ipv6-conflict-enable!
      |   +--rw preempt-enable?    boolean
    +--rw damp!
      | +--rw tx-off?                boolean
      | +--rw (level)?
      | | +--:(auto)
      | | | +--rw auto
      | | | | +--rw level?          damp-level-type
      | | +--:(manual)
      | | | +--rw manual
      | | | | +--rw suppress          uint32
      | | | | +--rw reuse              uint32
      | | | | +--rw max-suppress-time  uint16
      | | | | +--rw half-life-period  uint16
    +--rw auto-recovery-times
      | +--rw auto-recovery-time* [error-down-type]
      |   +--rw error-down-type    error-down-type
      |   +--rw time-value          uint32
    +--rw interfaces
      | +--rw interface* [name]
      | | +--rw name                pub-type
      | | +--rw class?              class-type
      | | +--rw type?               port-type
      | | +--rw parent-name?        -> /ifm,
      | | +--rw number?              string
```

Concept "Interface"

Ontology development efforts (focus on YANG)

- Linked Open Terms (LOT) methodology [1]
 - Mature methodology, inspired by agile software development
 - Collaboration between domain experts and ontology developers
 - Used in development of standard ontologies (e.g., ETSI SAREF)
- Semi-automatic extraction of knowledge
 - Extract knowledge by analyzing structure of YANG module
 - Examples □ YANG list/container refer to entities, YANG leaf to properties/relationships
- MAYA paper [2]
 - Unsupervised ML. Node similarity between YANG leaf nodes
 - Not only structure, but semantics in YANG identifiers, descriptions, type, and references

1. LOT Methodology - <https://lot.linkeddata.es>
2. MAYA: Exploring multiform attributes of node to align YANG data models - <https://www.sciencedirect.com/science/article/abs/pii/S1389128622005722>



What's next?

- Ontology development is a hard task
 - Semantic modelling skills
 - Domain expertise
 - Needed for creation of knowledge graphs [1]
 - ... and we are just talking about YANG, thus far
 - Looking for feedback/interest from NRMG
 - Explore methodologies/tooling to derive ontologies from YANG models
 - Semantic annotation of YANG data
 - Evolution of YANG? YANBOG? [2]
 - Separate file containing semantic metadata?
 - Leverage YANG annotations? [3]
1. Research Challenges in Coupling Artificial Intelligence and Network Management - <https://datatracker.ietf.org/doc/draft-irtf-nrmg-ai-challenges/>
 2. NETMOD Mailing list – “YANG to be replaced by YANBOG? The future of YANG ...”
 3. RFC 7952: Defining and Using Metadata with YANG - <https://datatracker.ietf.org/doc/rfc7952/>





This Communication is part of a project that has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N°101069732



THANK YOU !

Ignacio Dominguez
Martinez-Casanueva

✉ ignacio.dominguezmartinez@telefonica.com

🌐 www.telefonica.com

FOLLOW
US!



<https://aeros-project.eu>



[@AerosProject](https://twitter.com/AerosProject)



[aerOS Project](https://www.youtube.com/aerOS%20Project)



[/aeros-project](https://www.linkedin.com/company/aeros-project)



[/aerosproject](https://www.facebook.com/aerosproject)



[/aerosproject](https://www.instagram.com/aerosproject)

