Knowledge Graphs for Enhanced Cross-Operator Incident Management and Network Design

draft-tailhardat-nmop-incident-management-noria-02

IETF NMOP interim meeting - 21st, May 2025

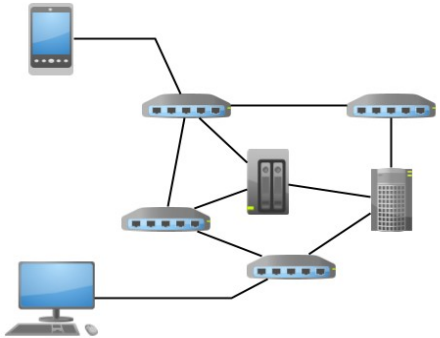
Lionel TAILHARDAT, Orange Research, lionel.tailhardat@orange.com
Fano RAMPARANY, Orange Research, fano.ramparany@orange.com
Pauline FOLZ, Orange Research, pauline.folz@orange.com

orange™

EURECOM
Sophia Antipolis

Context & motivations: abstracting networks & sharing behavioral models

We have a network to manage
… towards handling its complexity



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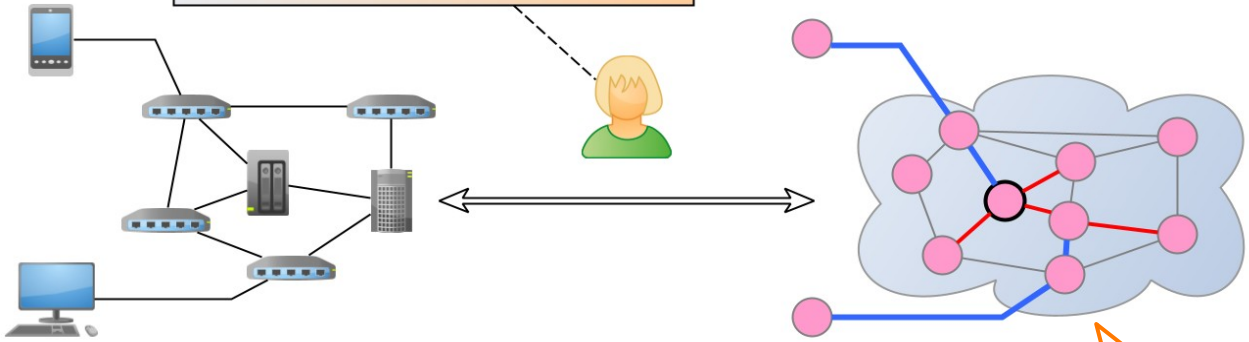
We could build abstract representations of networks for advancing NetOps and SecOps, don't we?



We have a network to manage
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… looks like a (knowledge) graph!

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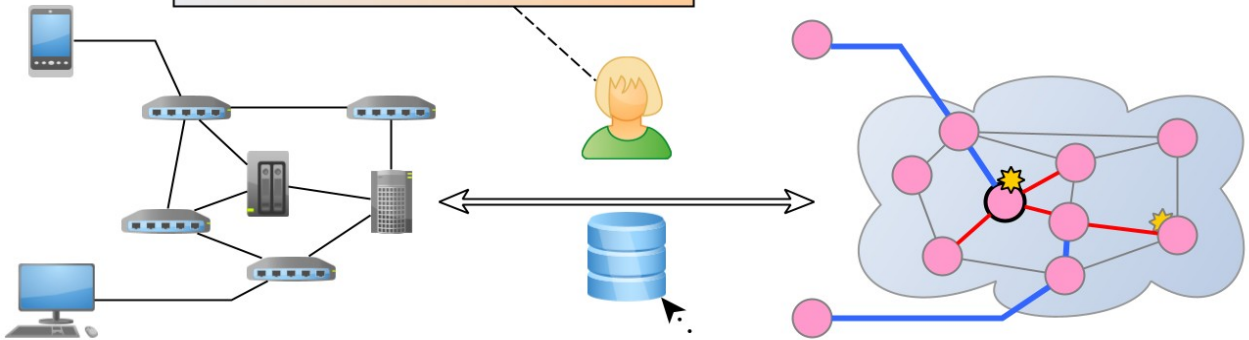
Many personas, many requirements
Supervision technicians
Network & support engineers
Automation engineers



I need multiple knowledge facets (e.g. tech data, ops, locations, org) to get context for situation understanding and decision making, notably when dealing with complex networks.

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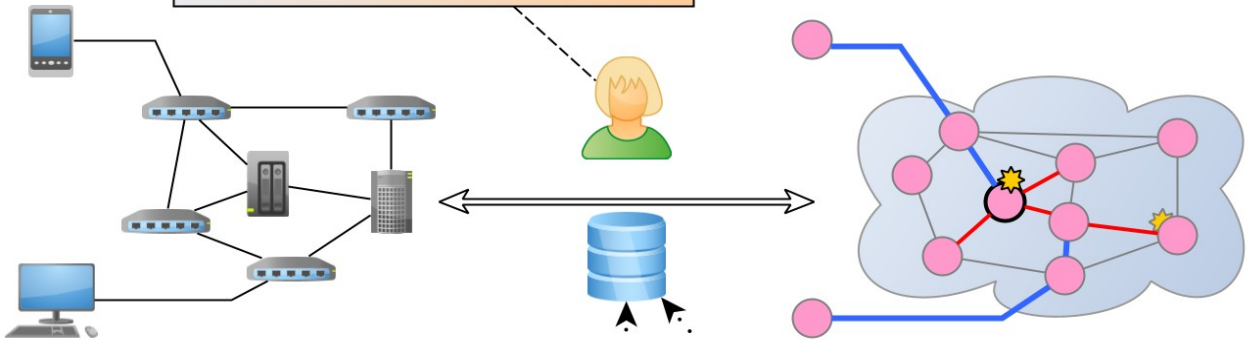

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I need a way to abstract the network architecture and behavior in order to share technical models with practitioners and plan improvements of the network design.

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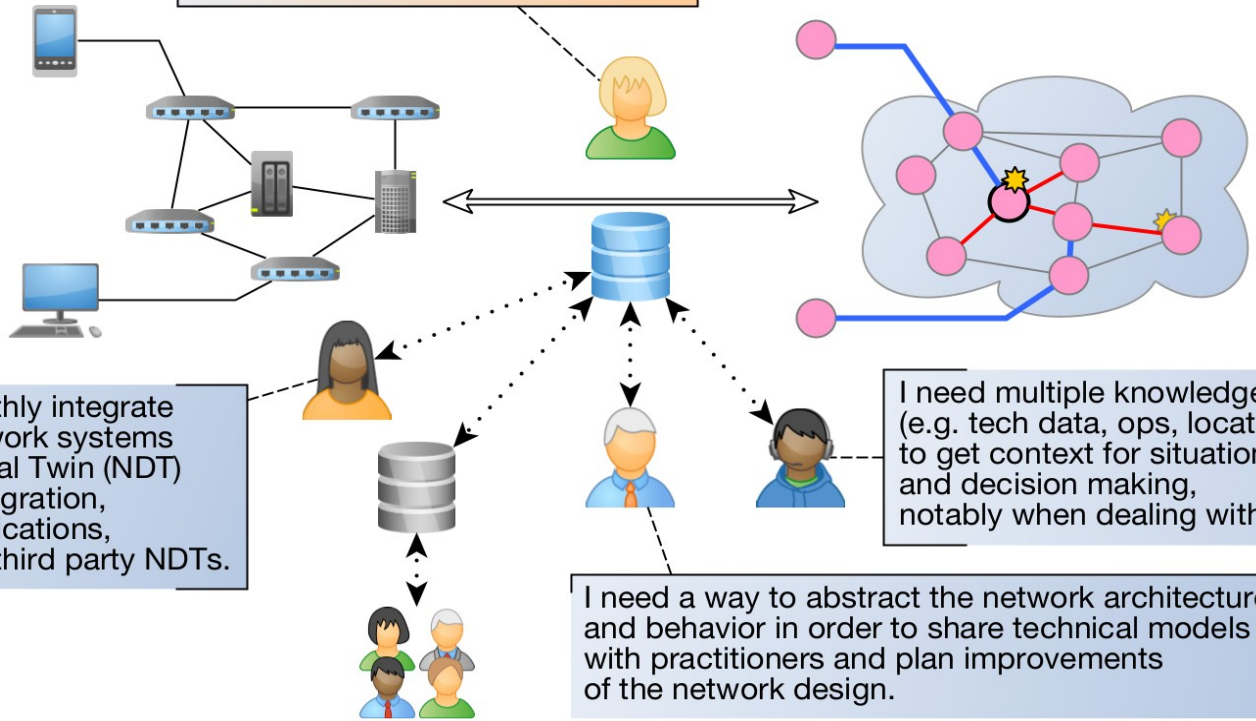

I need a way to smoothly integrate new devices and network systems into the Network Digital Twin (NDT) with lossless data integration, bidirectional communications, and easy linking with third party NDTs.

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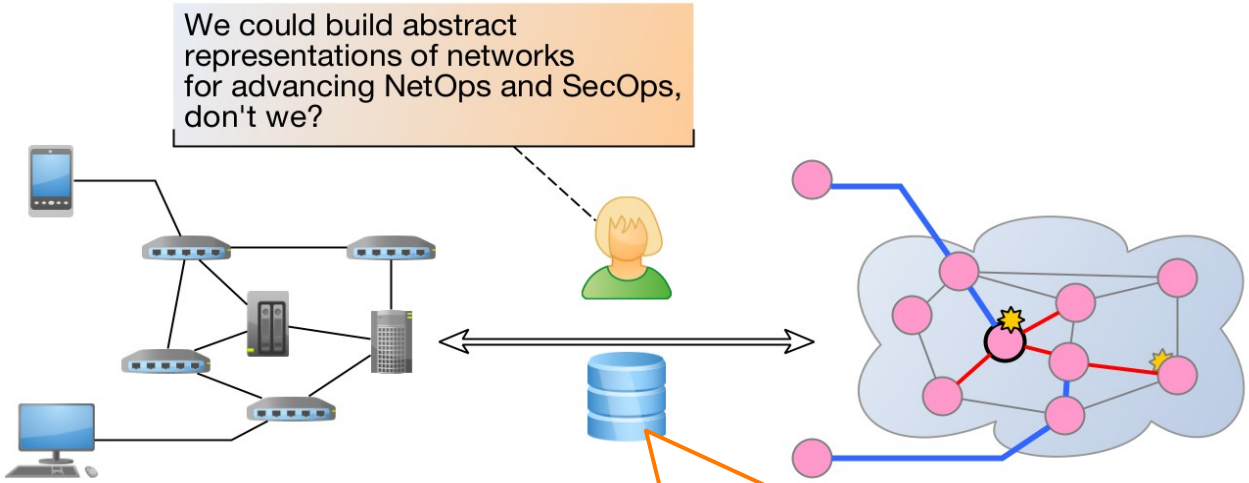

IETF NMOP interim meeting n°3, 2024-09-11
draft-tailhardat-nmop-incident-management-noria-01
[I-D, presentation] … raised the ideas that:

Data Knowledge graph as a combination of a Digital Map [I-D] with operational data and Operational Support Systems (OSS) data.

Opportunity YANG-based configuration data can be converted to build a Digital Map, thereby connecting the Decision Support Systems (DSS) with network production.

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Authors: L. Tailhardat, *Orange Research*
R. Troncy, *EURECOM*
Y. Chabot, *Orange Research*
F. Ramparany, *Orange Research*
P. Folz, *Orange Research*

Knowledge Graphs for Enhanced Cross-Operator Incident Management and Network Design

Abstract

Operational efficiency in incident management on telecom and computer networks requires correlating and interpreting large volumes of heterogeneous technical information. Knowledge graphs can provide a unified view of complex systems through shared vocabularies. YANG data models enable describing network configurations and automating their deployment. However, both approaches face challenges in vocabulary alignment and adoption, hindering knowledge capitalization and sharing on network designs and best practices. To address this, the concept of a IT Service Management (ITSM) Knowledge Graph (KG) is introduced to leverage existing network infrastructure descriptions in YANG format and enable abstract reasoning on network behaviors. The key principle to achieve the construction of such ITSM-KG is to transform YANG representations of network infrastructures into an equivalent knowledge graph representation, and then embed it into a more extensive data model for Anomaly Detection (AD) and Risk Management applications. In addition to use case analysis and design pattern analysis, an experiment is proposed to assess the potential of the ITSM-KG in improving network quality and designs.

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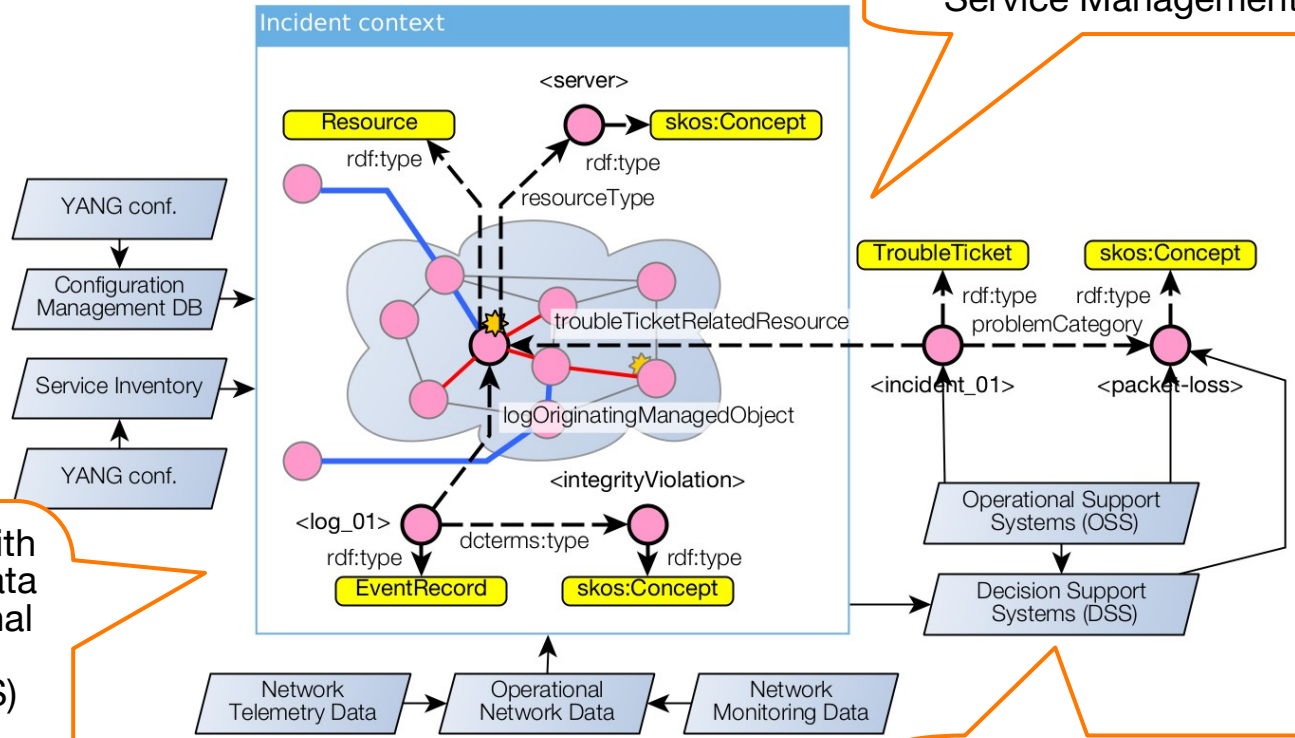
Knowledge graph for IT Service Management!



Digital Map with operational data and Operational Support Systems (OSS) data = **heterogeneous data sources**

Knowledge graph-based NetOps & SecOps

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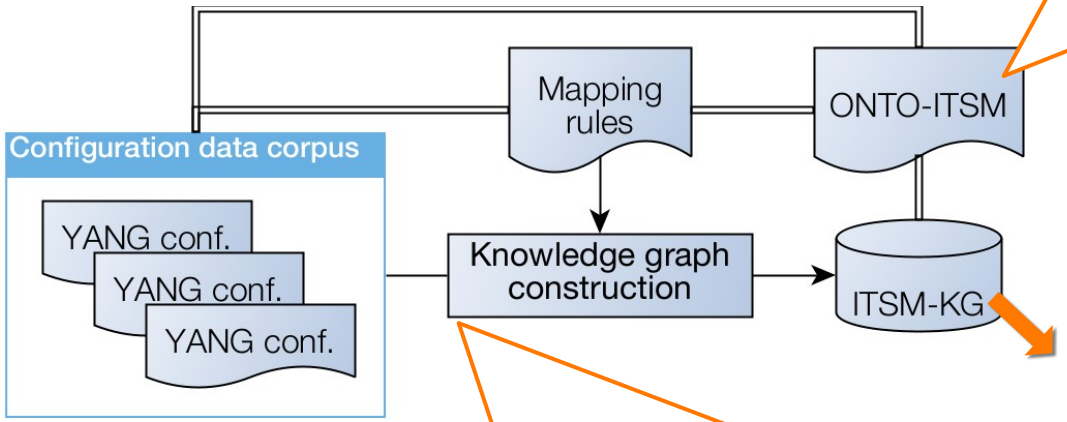
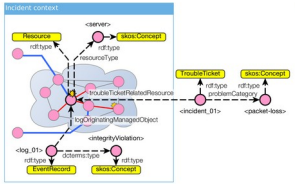
ONTO-ITSM Brings a unified view of the network and its ecosystem, i.e. enables querying/traversing the ITSM-KG with a shared vocabulary.



IT Service Management Knowledge Graph



YANG conf. The YANG language is the current standard in network management and will remain so. Including this data—without loss of information and while respecting each operator's specifics (e.g. choice of YANG modules)—can be done by reflecting on **how to project YANG configuration data into the broader ITSM-KG discourse domain**.

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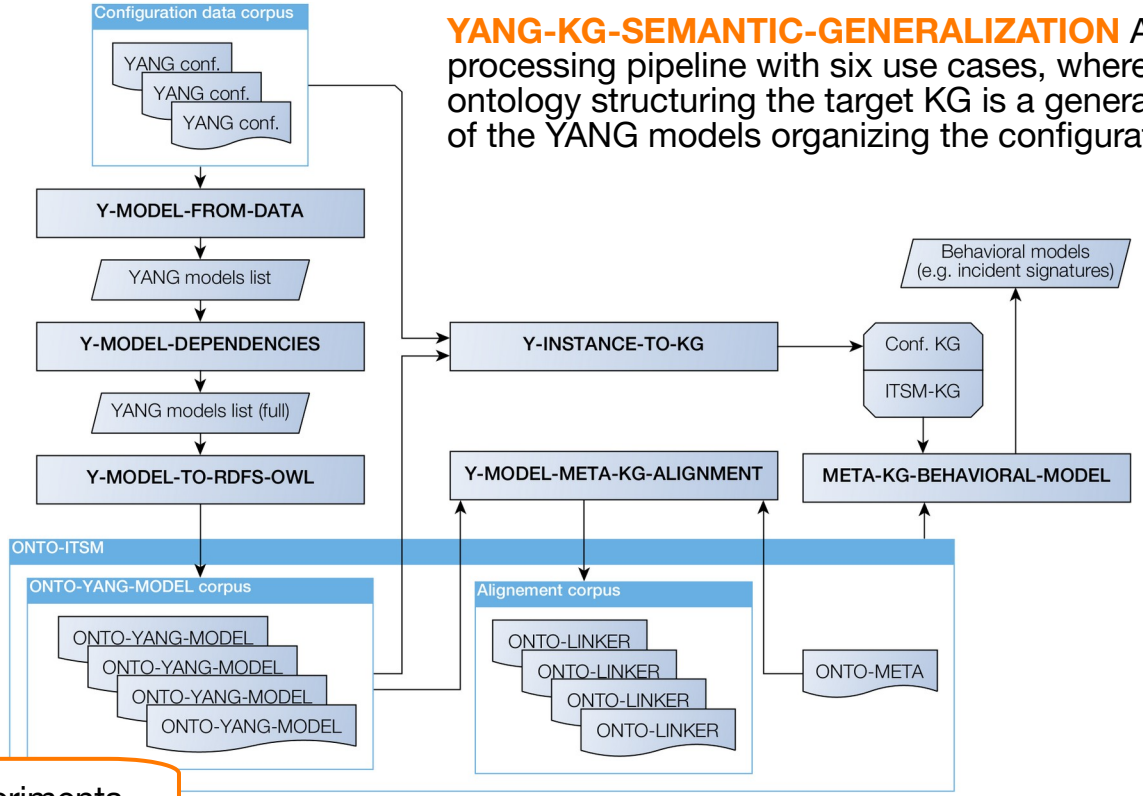

YANG-KG-SEMANTIC-GENERALIZATION A data processing pipeline with six use cases, where the ontology structuring the target KG is a generalization of the YANG models organizing the configuration data.

Call for experiments

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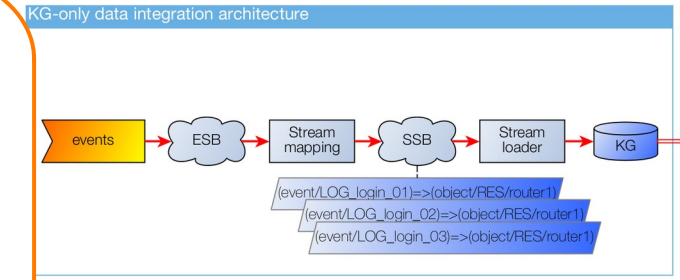
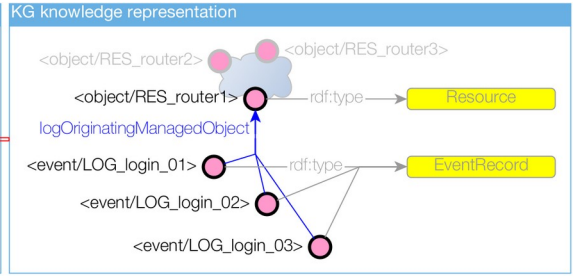
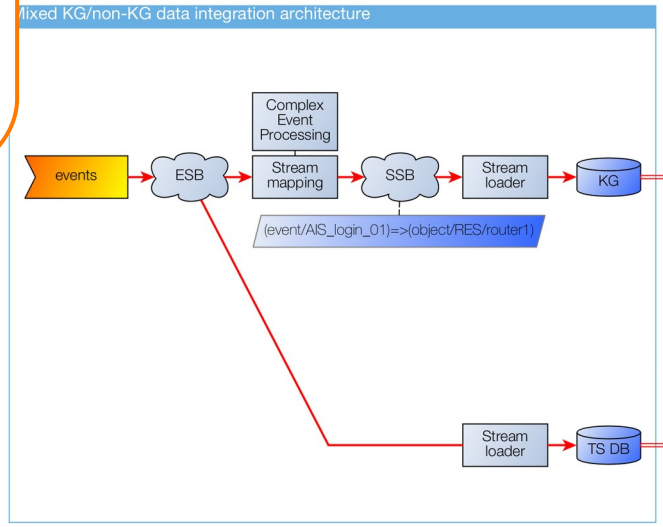
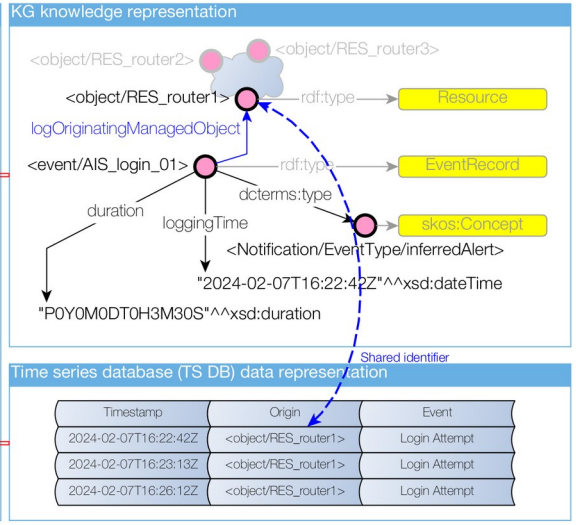
Handling Event Streams Scenarios for constructing a ITSM-KG through an Extract-Transform-Load (ETL) data integration pipeline.

Event streams can be high-paced: it could be beneficial to **leverage input/output (I/O) performance optimizations specific to each type of database management system** (DBMS), such as Time-Series DataBases (TSDBs) for streaming data and graph databases for knowledge graphs.









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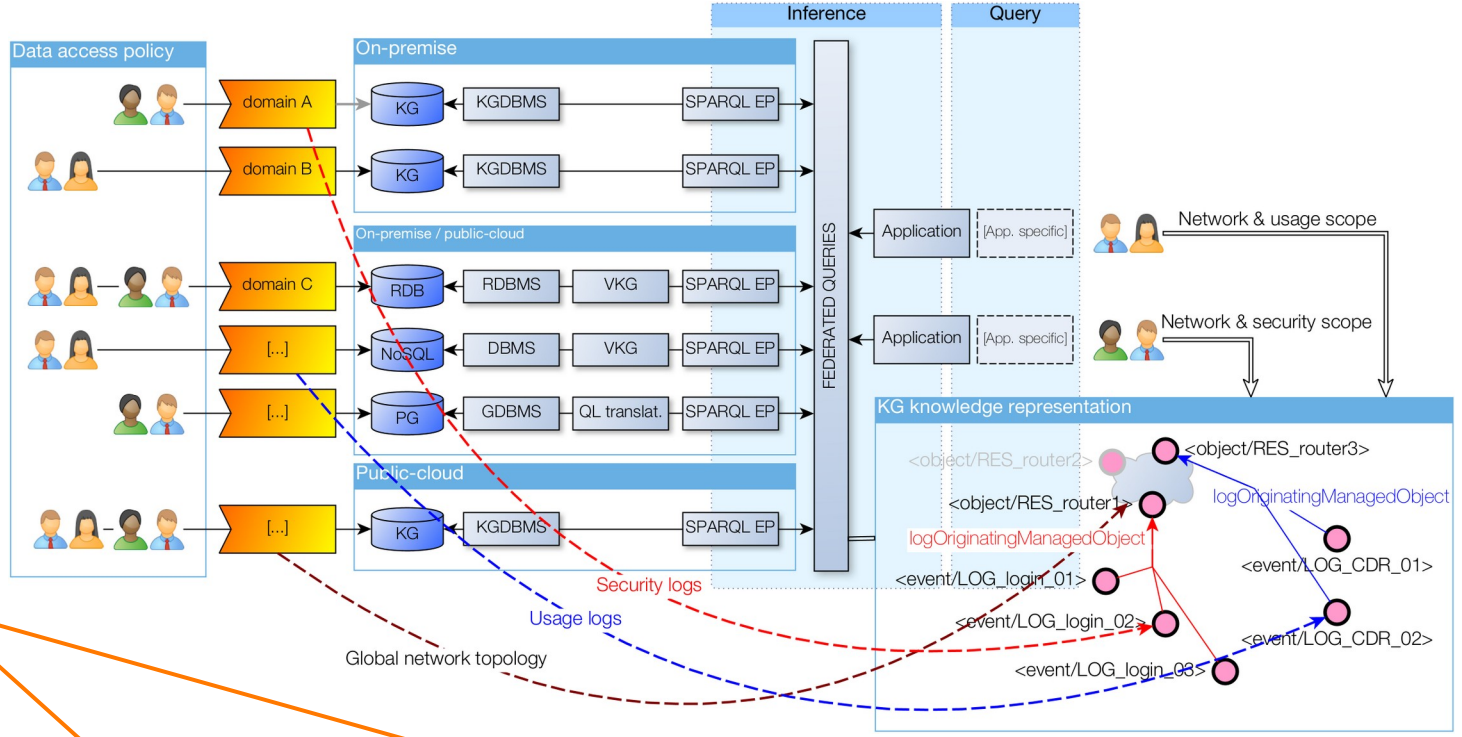

Federated querying over a multi-siloed graph

Providing **unified access** to data distributed across various technological platforms and stakeholders thanks to SPARQL Federated Queries and the use of a shared ONTO-ITSM across data management platforms.

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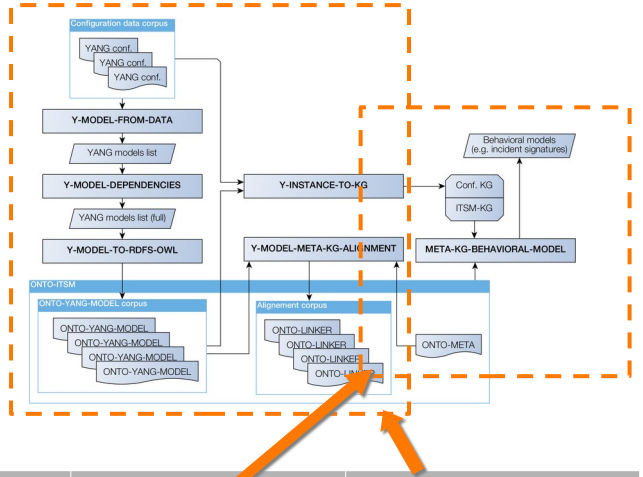
Implementation status ...

Two complementary experiments available as for now.



YANG-KG-SEMANTIC-GENERALIZATION use cases	**NORIA** draft v01	**YANG2OWL** draft v02
Y-MODEL-FROM-DATA	no	potential
Y-MODEL-DEPENDENCIES	no	yes
Y-MODEL-TO-RDFS-OWL	no	yes
Y-INSTANCE-TO-KG	potential	yes
Y-MODEL-META-KG-ALIGNMENT	potential	potential
META-KG-BEHAVIORAL-MODEL	yes	no

Focusing on the YANG2OWL approach ...

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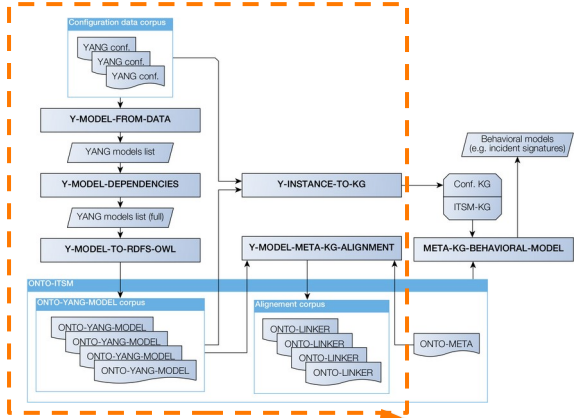

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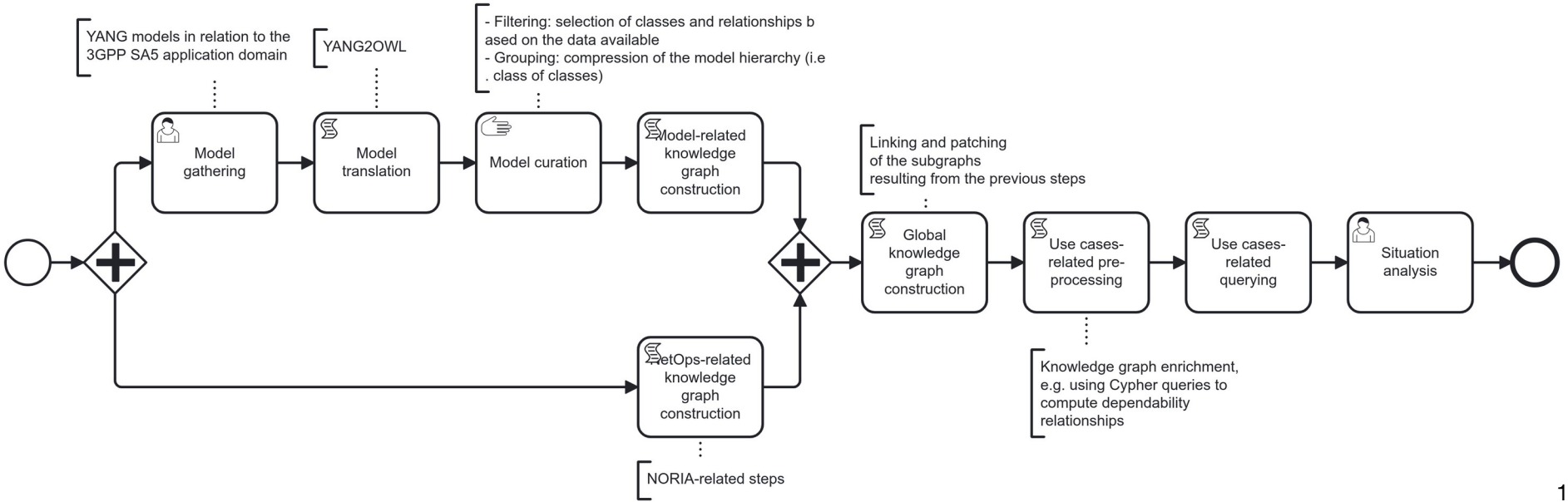
The YANG2OWL approach with an example of implementation -- §5.2.2.4

Data Virtualized 5G infrastructure (YANG based) + network ecosystem (other sources)

Operational context Network change management process -- impact analysis

Typical case For a scheduled operation on a leaf node (i.e. a network element in a 2-tier spine-leaf architecture), return all the servers connected to the leaf, all the Virtual Machines (VMs) hosted on these servers, all the Network Functions (NFs) deployed on these VMs, and ideally all the telecom services using these NFs.



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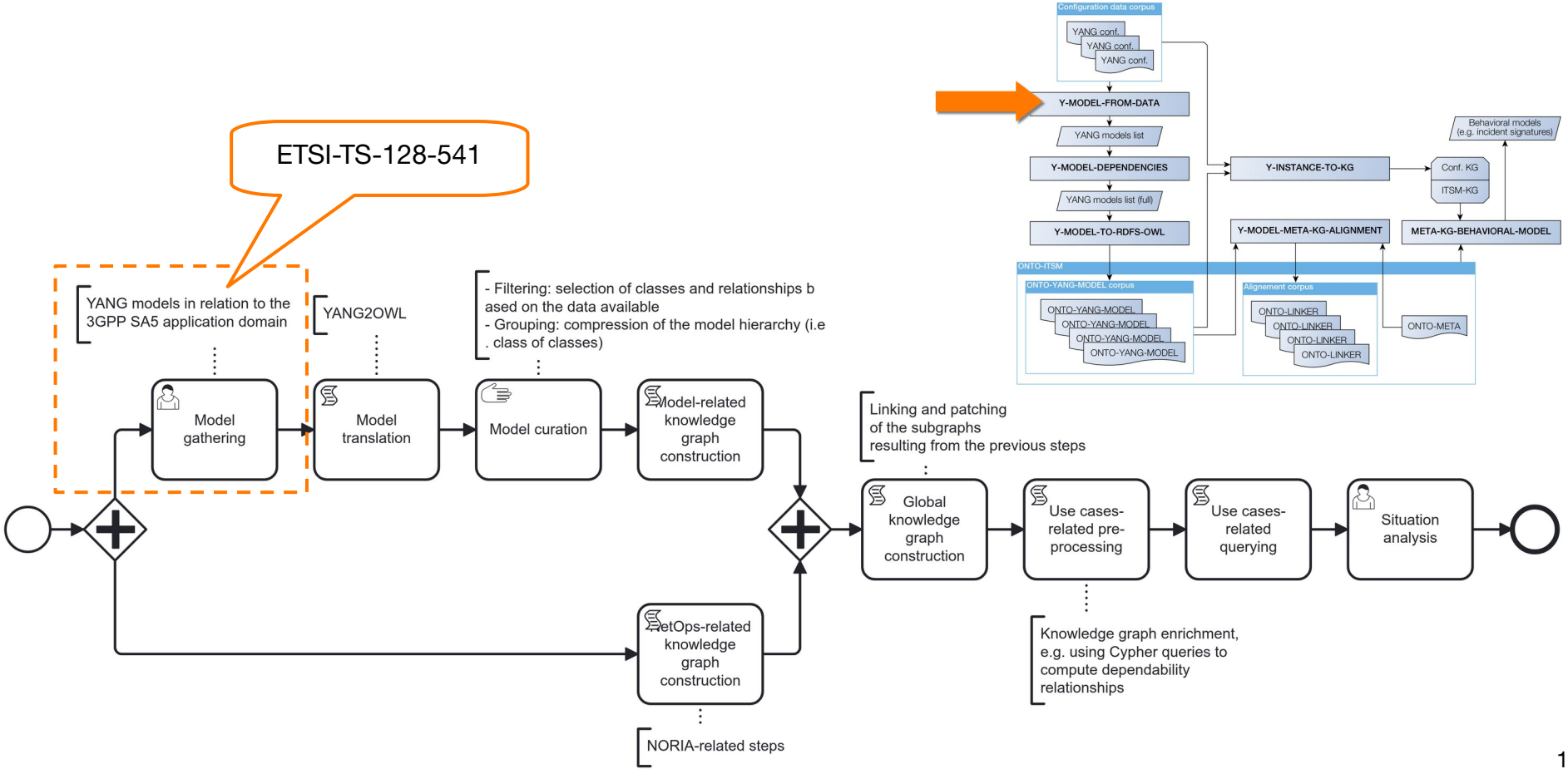
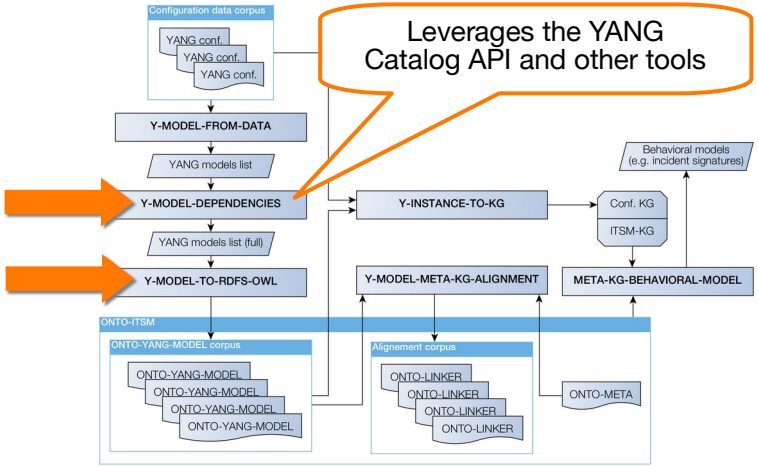


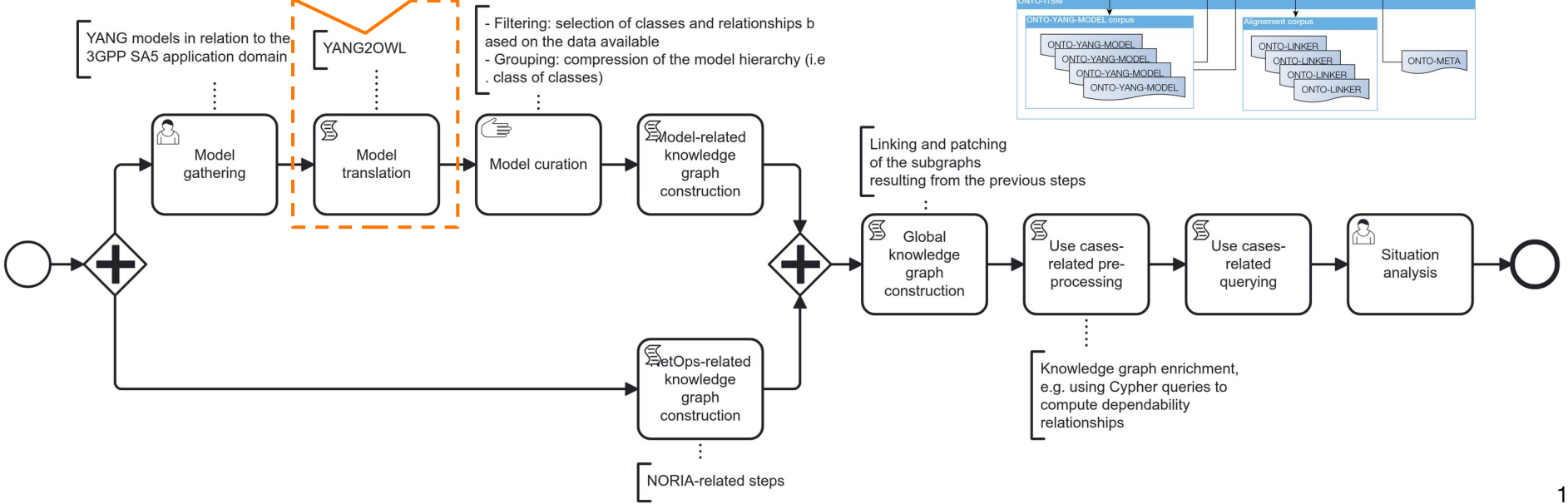
The YANG2OWL approach with an example of implementation -- §5.2.2.4

YANG2OWL converter (draft v02 §5.2.2.2)

Mapping rules between YANG constructs and OWL concepts :

- **{container, list} ↦ OWL classes**.
  The name of the OWL class correponds to the name of the container or list in the YANG model.
- **{leaf, leaf-list} ↦ OWL data properties**.
  The name of the OWL data property corresponds the name of the leaf or leaf-list in the YANG model.





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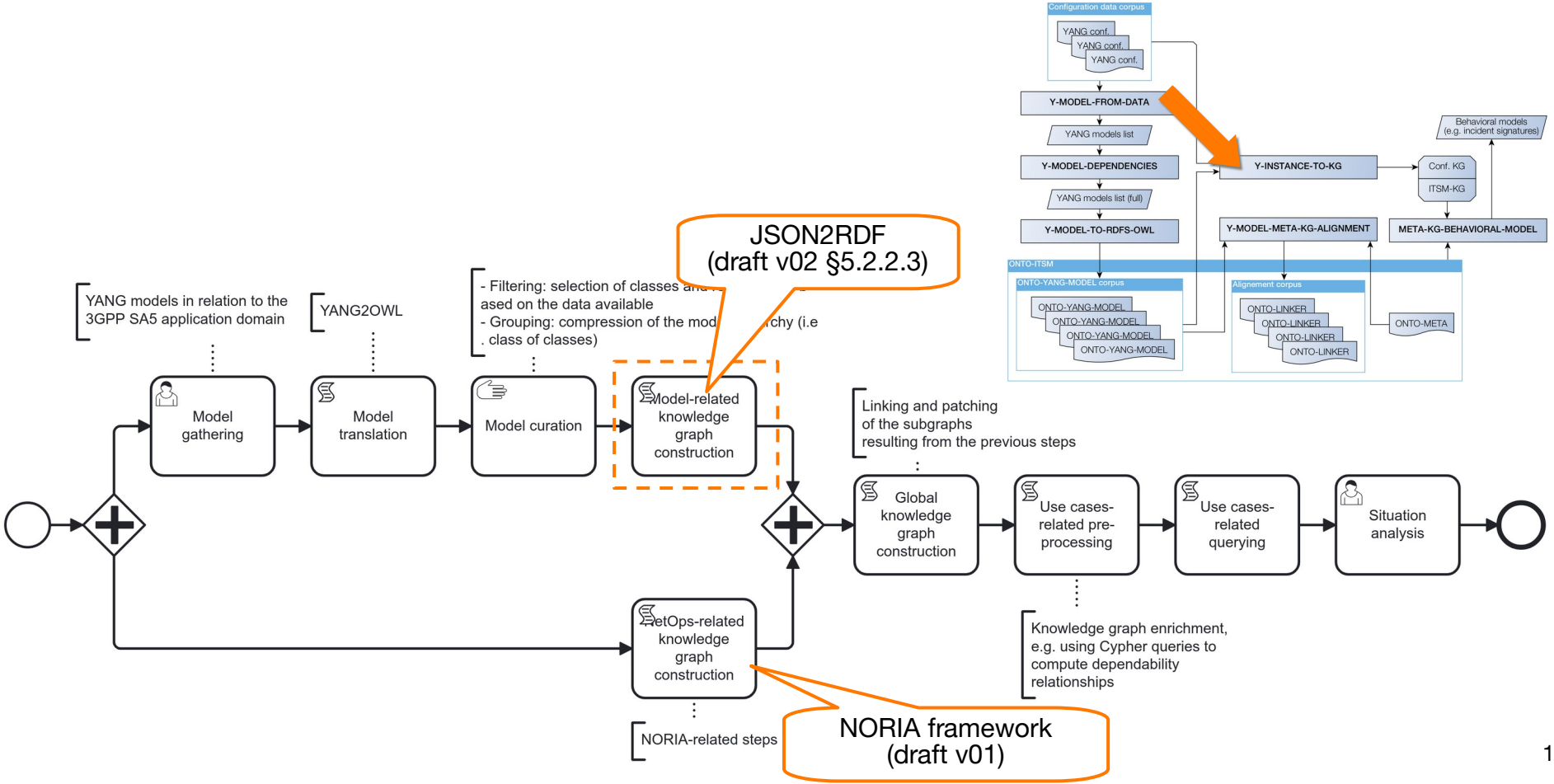

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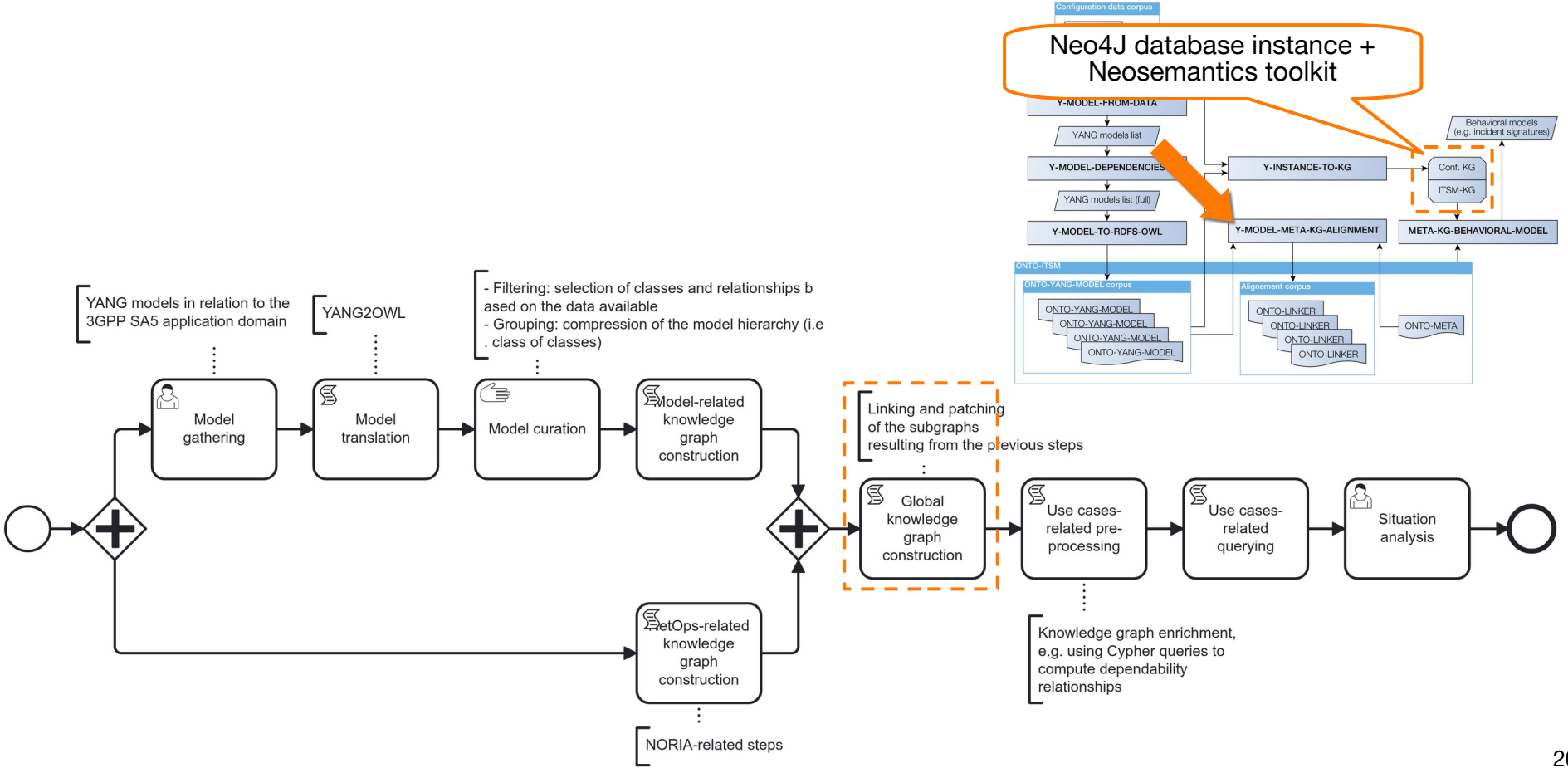


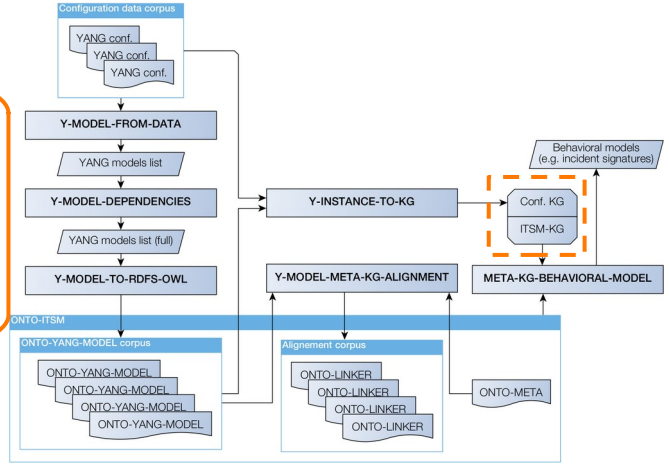
The YANG2OWL approach with an example of implementation -- §5.2.2.4

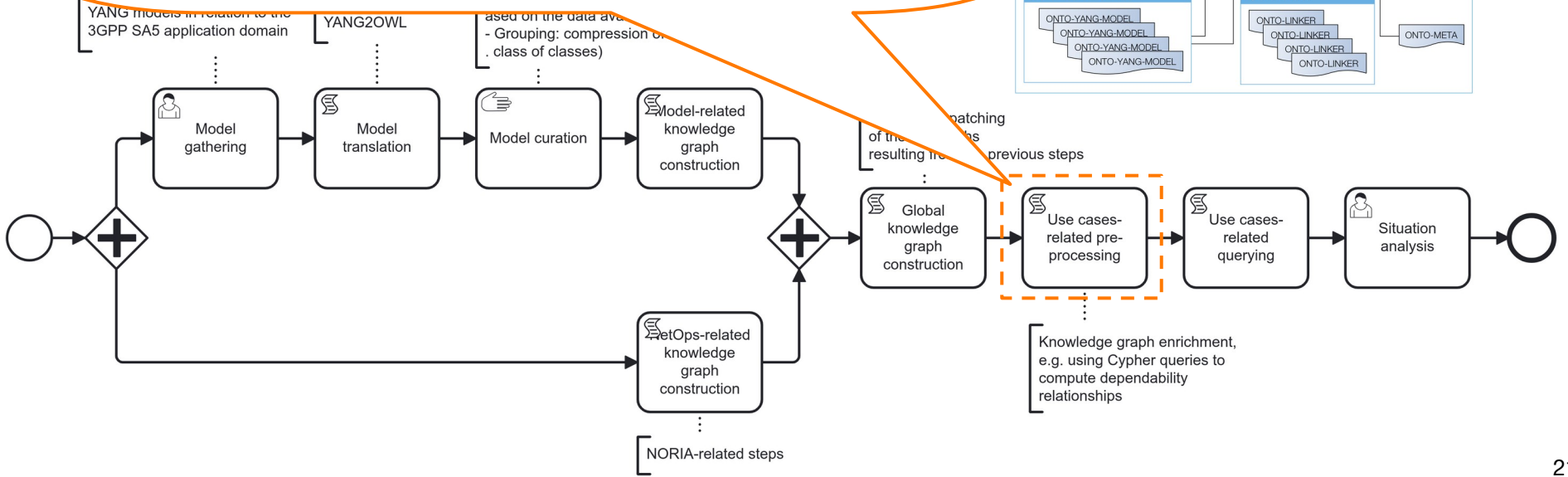
Dependency calculation query (business rule, Cypher syntax)

```
MATCH (c:ManagedFunction)--(n:namespace)--(k:ClusterKubernetes)
MERGE (c)-[d:DEPENDS_ON]→(k)
```

Subclass inference query (Cypher syntax, Neo4J specific)

```
MATCH (m)<-[:subClassOf]-(x)<-[:type]-(c)
WHERE m.uri CONTAINS 'ManagedFunction'
SET c:ManagedFunction
```





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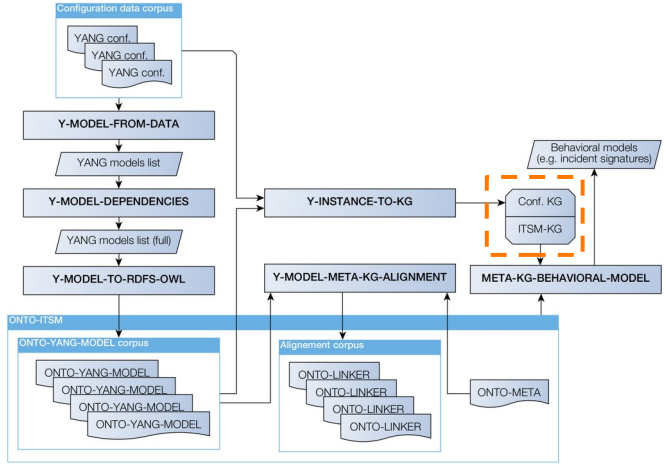

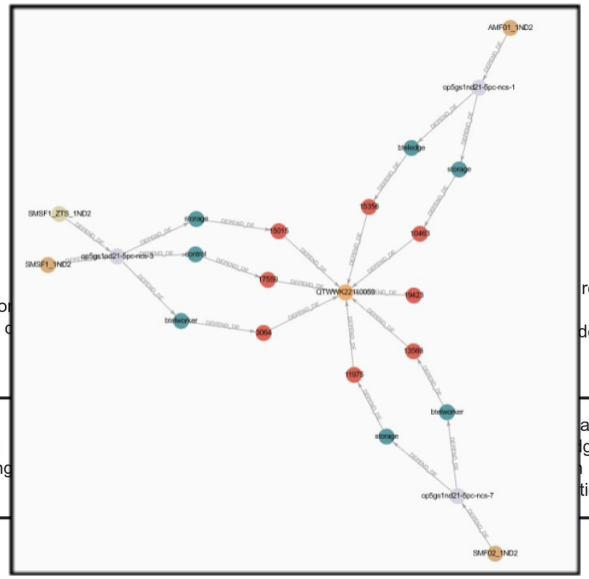

YANG models in relation
3GPP SA5 application c

relationships b

del hierarchy (i.e

Model gathering

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ge
tion

Linking and patching of the subgraphs resulting from the previous steps

Global knowledge graph construction

Use cases-related pre-processing

Use cases-related querying

Situation analysis

User query (Cypher syntax) for rendering dependency relationships in a Neo4j NeoDash display

```
MATCH (e1) WHERE e1.resourceHostName = $neodash_ressource_hostname
MATCH q1 = (e1) ((w)<-[:DEPENDS_ON]-(t)) {0,8}
UNWIND t AS impacts
RETURN DISTINCT impacts.resourceHostName
```

draft-tailhardat-nmop-incident-management-noria-02

https://datatracker.ietf.org/doc/draft-tailhardat-nmop-incident-management-noria/

Problem Building an ITSM Knowledge Graph that uses YANG-based configuration data while abstracting network details for learning and sharing behavioral models.

Approach Knowledge representation using SemWeb technologies, generalization of YANG models for configuration data, an extended Digital Map combining configuration with operational and OSS data, and a data processing pipeline for experimentation.

Next Call for experiments and contributions on the draft-tailhardat-nmop-incident-management-noria proposal.

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Implementation status in short ...

NORIA Means for building a **unified view of complex ICT systems** and learning/exploiting/sharing network behavioral models.

YANG2OWL **Streamlines the development of NDT architectures** based on knowledge graphs and simplifies ITSM-KG updates when YANG modules change. It notably automates the Ontology Implementation and Ontology Update activities of the LOT4KG methodology [LOT4KG-2024].

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Y-INSTANCE-TO-KG
Y-MODEL-META-KG-ALIG
META-KG-BEHAVIORAL-M

Ideas for new opportunities ...

- Learning and sharing anomaly models using the « **AnTagOnIst** » (Anomaly Tagging On hIstorical data) [GitHub] framework?
- Building the ITSM-KG with the « **Declarative Construction** of Knowledge Graphs from **NETCONF Data Sources** » (Dominguez, et al. - 2025) [SWJ] toolkit?
- Combine the « **YANG2RDF** » and « YANG2OWL » approaches?
- Reflect on how to **automate the Y-MODEL-META-KG-ALIGNMENT** use case.
- Check if there exists **universal YANG ⇆ RDFS/OWL translation** principles?
- Reflect on how to ensure **reliable retrieval of dependencies between YANG modules** for the Y-MODEL-DEPENDENCIES use case.