

ETSI GR ENI 031 V4.1.1 (2024-05)



Experiential Networked Intelligence (ENI); Construction and application of fault maintenance network knowledge graphs

Document Preview

[ETSI GR ENI 031 V4.1.1 \(2024-05\)](https://standards.iteh.ai/catalog/standards/etsi/34353dfe-9960-4459-a02d-451c0c38ca74/etsi-gr-eni-031-v4-1-1-2024-05)

<https://standards.iteh.ai/catalog/standards/etsi/34353dfe-9960-4459-a02d-451c0c38ca74/etsi-gr-eni-031-v4-1-1-2024-05>

Disclaimer

The present document has been produced and approved by the Experiential Networked Intelligence (ENI) ETSI Industry Specification Group (ISG) and represents the views of those members who participated in this ISG.
It does not necessarily represent the views of the entire ETSI membership.

Reference

DGR/ENI-0031v411_Net-know-grap

Keywords

access, algorithm, wireless ad-hoc network

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Important notice

The present document can be downloaded from:

<https://www.etsi.org/standards-search>

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the prevailing version of an ETSI deliverable is the one made publicly available in PDF format at www.etsi.org/deliver.

Users of the present document should be aware that the document may be subject to revision or change of status.

Information on the current status of this and other ETSI documents is available at

<https://portal.etsi.org/TB/ETSIDeliverableStatus.aspx>

If you find errors in the present document, please send your comment to one of the following services:

<https://portal.etsi.org/People/CommitteeSupportStaff.aspx>

If you find a security vulnerability in the present document, please report it through our

Coordinated Vulnerability Disclosure Program:

<https://www.etsi.org/standards/coordinated-vulnerability-disclosure>

Notice of disclaimer & limitation of liability

The information provided in the present deliverable is directed solely to professionals who have the appropriate degree of experience to understand and interpret its content in accordance with generally accepted engineering or other professional standard and applicable regulations.

No recommendation as to products and services or vendors is made or should be implied.

No representation or warranty is made that this deliverable is technically accurate or sufficient or conforms to any law and/or governmental rule and/or regulation and further, no representation or warranty is made of merchantability or fitness for any particular purpose or against infringement of intellectual property rights.

In no event shall ETSI be held liable for loss of profits or any other incidental or consequential damages.

Any software contained in this deliverable is provided "AS IS" with no warranties, express or implied, including but not limited to, the warranties of merchantability, fitness for a particular purpose and non-infringement of intellectual property rights and ETSI shall not be held liable in any event for any damages whatsoever (including, without limitation, damages for loss of profits, business interruption, loss of information, or any other pecuniary loss) arising out of or related to the use of or inability to use the software.

Copyright Notification

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.

The content of the PDF version shall not be modified without the written authorization of ETSI.

The copyright and the foregoing restriction extend to reproduction in all media.

© ETSI 2024.
All rights reserved.

Contents

Intellectual Property Rights	5
Foreword.....	5
Modal verbs terminology.....	5
1 Scope	6
2 References	6
2.1 Normative references	6
2.2 Informative references.....	6
3 Definition of terms, symbols and abbreviations.....	7
3.1 Terms.....	7
3.2 Symbols.....	7
3.3 Abbreviations	8
4 Introduction	8
4.1 Background of network fault management knowledge graph construction	8
4.2 Values of network fault maintenance knowledge graph.....	9
5 Construction of wireless network fault maintenance knowledge graphs	9
5.1 Framework of network fault maintenance knowledge graph construction process	9
5.2 Data acquisition and processing for knowledge graph	12
5.2.1 Content and format of data collection.....	12
5.2.2 Data normalization.....	12
5.3 Ontology design	13
5.3.1 Diagram of ontology	13
5.3.2 Definition of types and attributes of wireless fault maintenance knowledge entities	14
5.3.3 Definition of relationship of wireless fault maintenance knowledge entities	17
5.4 Knowledge Graph Quality Evaluation Methods.....	17
6 Application of wireless network fault maintenance knowledge graph.....	18
6.1 Knowledge reasoning	18
6.1.1 Motivation.....	18
6.1.2 Functional Requirements	18
6.1.3 Interface requirements	19
6.2 Knowledge storage and query	19
6.2.1 Motivation.....	19
6.2.2 Functional Requirements	19
6.2.3 Interface requirements	20
7 Use Cases	21
7.1 Cases of knowledge graph construction	21
7.1.1 Use Case #1-1: Knowledge graph of wireless network quality fault handling	21
7.1.1.1 Overview	21
7.1.1.2 Data Acquisition and processing.....	21
7.1.1.3 Ontology/schema design	22
7.1.1.4 Knowledge Extraction and knowledge fusion.....	23
7.1.1.5 Knowledge graph quality evaluation.....	23
7.2 Cases of knowledge graph application	24
7.2.1 Use Case #2-1: Fault tracing in Wireless Network.....	24
7.2.1.1 Overview	24
7.2.1.2 Motivation.....	24
7.2.1.3 Actors and roles	24
7.2.1.4 Operational flow of actions	24
7.2.1.5 Post-conditions	25
7.2.2 Use Case #3-1: Intelligent Management of Home LAN.....	25
7.2.2.1 Overview	25
7.2.2.2 Motivation.....	25
7.2.2.3 Actors and roles	25

7.2.2.4	Initial context condition	25
7.2.2.5	Operational flow of actions	26
7.2.2.6	Post-conditions	26
8	Research on cross network fields fault maintenance knowledge graphs construction methods (e.g. access networks).....	27
9	Conclusions	27
Annex A:	Change history	29
History		30

iTeh Standards
(<https://standards.iteh.ai>)
Document Preview

[ETSI GR ENI 031 V4.1.1 \(2024-05\)](https://standards.iteh.ai/catalog/standards/etsi/34353dfe-9960-4459-a02d-451c0c38ca74/etsi-gr-eni-031-v4-1-1-2024-05)

<https://standards.iteh.ai/catalog/standards/etsi/34353dfe-9960-4459-a02d-451c0c38ca74/etsi-gr-eni-031-v4-1-1-2024-05>

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: "*Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards*", which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (<https://ipr.etsi.org/>).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™** and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM®** and the GSM logo are trademarks registered and owned by the GSM Association.

Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) Experiential Networked Intelligence (ENI).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

1 Scope

The purpose of the present document is to describe use cases and a construction method of knowledge graphs that are used for fault maintenance. The present document focus on the following topics:

- defines the data requirements;
- defines a schema design;
- describes the knowledge application interface for fault maintenance knowledge graphs.

In addition to the main target related to the construction of fault maintenance network knowledge graphs, obtaining computer-readable and writable network fault maintenance domain knowledge and enabling learning and reasoning of relevant algorithm models of fault self-repair are also envisaged.

The present document will encompass research and investigation activities that will address wireless networks at the first stage. Subsequent efforts possibly will extend the work into access networks.

NOTE: The general solutions for knowledge graph and knowledge management are out of the scope of the present document.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long-term validity.

The following referenced documents are not necessary for the application of the present document, but they assist the user with regard to a particular subject area.

- [i.1] ETSI GR ENI 004 (V3.1.1): "Experiential Networked Intelligence (ENI); Terminology".
- [i.2] ETSI GS ENI 005 (V3.1.1): "Experiential Networked Intelligence (ENI); System Architecture".
- [i.3] ETSI GR ENI 010 (V1.1.1): "Experiential Networked Intelligence (ENI); Evaluation of categories for AI application to Networks".
- [i.4] TM Forum IG1218: "Autonomous Networks Business Requirements and Architecture".
- [i.5] "Autonomous Systems - An Architectural Characterization, Joseph Sifakis", Verimag Laboratory, 2019.
- [i.6] [ETSI GS ENI 019 \(V3.1.1\)](#): "Experiential Networked Intelligence (ENI); Representing, Inferring, and Proving Knowledge in ENI".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI GR ENI 004 [i.1] , ETSI GS ENI 005 [i.2], ETSI GR ENI 010 [i.3] and the following apply:

co-reference resolution: task of finding all expressions in a text that refer to the same real-world entity

data cleansing: process of detecting and correcting (or removing) incomplete, incorrect, inaccurate, or corrupt data from being further processed

entity disambiguation: process of finding references in a dataset that refer to the same entity

extraction: activity of transforming valuable information into structured data from input data of different sources and structures:

- **attribute extraction:** extract detailed features describing entities/relationships/events from input data
- **entity extraction:** identify named entities from input data
- **knowledge extraction:** extracting entities, relationships, and new knowledge from patterns or inference from data
- **relationship extraction:** extract various semantic associations between different entities from input data

knowledge discovery: finding new knowledge from existing knowledge

knowledge entity: concept of reflecting specific things in the knowledge graph

knowledge fusion: process of combining knowledge from multiple sources to create a more comprehensive and accurate representation of the system

knowledge graph: structured representation of knowledge that uses a graph data structure and formal logic to represent entities and their relationships

knowledge integration: combining knowledge from different sources in a way that preserves the semantics of the knowledge

knowledge reasoning: process of using knowledge to draw new conclusions:

- **graph-based knowledge reasoning:** embed high-dimensional knowledge graphs into low latitude continuous vector spaces

NOTE: They represent entities and relationships as numerical vectors for computation, and combine other algorithms to achieve reasoning, including methods such as distributed feature representation, Graph Neural Network (GNN) algorithms.

- **rule-based knowledge reasoning:** mining and reasoning by defining or learning rules that exist in knowledge, including methods such as predicate logic reasoning, ontology reasoning, and random reasoning

ontology alignment: finding mappings between overlapping concepts in two or more ontologies to align them

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI GR ENI 004 [i.1], ETSI GS ENI 005 [i.2] and the following apply:

KaaS	Knowledge as a Service
KGC	Knowledge Graph Completion
KGQA	Knowledge Graph Question Answering
LAN	Local Area Network
MMKG	Multi-Modal Knowledge Graph
MR	Measurement Report
NFV	Network Function Virtualisation
R&D	Research and Development
RCA	Root Cause Analysis
RDF	Resource Description Framework
SDN	Software Defined Networking
SQL	Structured Query Language
WQMKG	Wireless Quality Maintenance Knowledge Graph

4 Introduction

4.1 Background of network fault management knowledge graph construction

The telecommunications industry has been exploring digitization, automation and intelligence, from focusing on customer service and business layer in the early stage of transformation, gradually extending to the internal management and operation layer, and then to the network layer. Initially, the telecommunications industry looked to reduce cost and complexity while increasing business and network agility by using SDN, NFV and cloud technologies. However, network automation based on SDN/NFV technology still cannot completely solve the problems caused by the large-scale deployment of various applications, such as the introduction and expansion of new network technologies in the future. A common problem faced by the industry is how to improve efficiency and throughput in a large-scale for the entire process, and how to continuously, rapidly and iteratively introduce new technologies.

Autonomous Networks (refer to GR ENI 010 [i.3]) was born in this context. By applying a variety of intelligent technologies and giving full play to the integration advantages, it will drive the telecommunications industry to an era where intelligence is embedded in the network. In order to achieve the ultimate goal of autonomous networks (refer to [i.4]), it is essential to transform the existing business models to some new production, business and collaboration models, including eKnowledge-as-a-Service operations model (KaaS). KaaS is about delivering the right knowledge to the right person in the right context at the right time via desktop, laptop or any mobile device.

According to the highly autonomous system architecture proposed by Joseph Sifakis, a Greek/French computer scientist and winner of the Turing Award in 2007, knowledge management is understood to become one of the key technical features of autonomous networks (refer to [i.5]). Constructing the knowledge graph of a telecommunication domain could be an important means to improve the level of network intelligence.

With the rapid development of communication networks in recent years, the number of network connections and network data are growing rapidly, the network structure is becoming more and more complex, and there are more and more faults. The traditional fault processing approach is difficult to handle the increasing number of network faults, which is mainly reflected in the following three aspects:

- Traditional OAMP relies on the experience of experts, but the experience of OAMP experts varies greatly. To accurately derive the root cause of the fault, the required skill level for OAMP personnel is very high.
- Thousands of operation and maintenance personnel deal with a large number of repetitive problems. The accumulation of operation and maintenance experience is slow and the processing efficiency is low.

- Reference documents, such as vendor manuals and lab documents created by operation and maintenance personnel based on their experience, do not have standardized terminology. For example, different vendors may name the same KPI differently, and calculate it using different formulas. This makes it difficult for the operation and maintenance personnel to use.

Due to the existence of these problems, the automatic and intelligent network fault diagnosis technology has attracted the attention of researchers, which are examining how to improve the collection of relevant context-aware telemetry to more rapidly diagnose and repair faults and protect services.

In view of this problem, the present document will describe research work on the application of knowledge graphs in the domain of telecommunication networks, integrating the experience of experts in the domains of telecommunications and information knowledge to build knowledge graphs for the telecommunications domain, and intelligently discover the root cause of faults by using the representation, reasoning and human-computer interaction technology of knowledge graphs. However, the construction of the whole domain knowledge graph of telecommunication network is a huge project that cannot be accomplished in a reasonable time frame (refer to ETSI GS ENI 019 [i.6]). Therefore, taking the wireless access network field as the starting point, the present document puts forward the construction schema of wireless access network fault maintenance knowledge graphs, so as to provide technical reference for promoting the cooperation of industrial ecological partners to jointly build the general ability of fault diagnosis in the telecommunication network domain.

4.2 Values of network fault maintenance knowledge graph

The knowledge graphs play two roles for R&D personnel in the process of fault maintenance:

- Horizontal integration of information. For example, different types of log files collected on site are organized according to the dimensions of entity objects. This makes it easy to perform Named Entity Recognition (NER). NER can be used for physical objects (e.g. a router or a geographic area), logical objects (e.g. a device interface or a VPN), events (e.g. faults and notifications, such as the uploading of a new configuration or that data is available) and other networking concepts. When troubleshooting, the R&D personnel can intuitively see some events (alarms and operations) on the knowledge graph corresponding to the instance of a network element. The knowledge graph can also display the events related to the instance object. After the 5G wireless access network log file is visualized using the knowledge graph, the time for the R&D personnel to analyse the log will be reduced.
- Transform the experience of OAMP expert personnel into a knowledge graph, enabling the knowledge from multiple personnel and reference works to be more easily accumulated, augmented with new information, and applied. This provides the potential to be edited into reasoning rules and reused in each existing network that uses similar technologies and devices.

The power of a knowledge graph is its use of logic to manage and represent complex data by creating interconnected models of entities and their relationships. This provides the ability to reason about ingested telemetry and prove its conclusions. This in turn helps improve the operator's experience.

NOTE: The reasoning rules transformed from expert experience in the knowledge graphs are for further study.

5 Construction of wireless network fault maintenance knowledge graphs

5.1 Framework of network fault maintenance knowledge graph construction process

The framework of the network fault maintenance knowledge graph construction process includes four steps: data acquisition and processing, ontology/schema design, knowledge extraction and knowledge fusion, knowledge verification. The main process of building the network fault maintenance knowledge graph is shown in Figure 5-1.

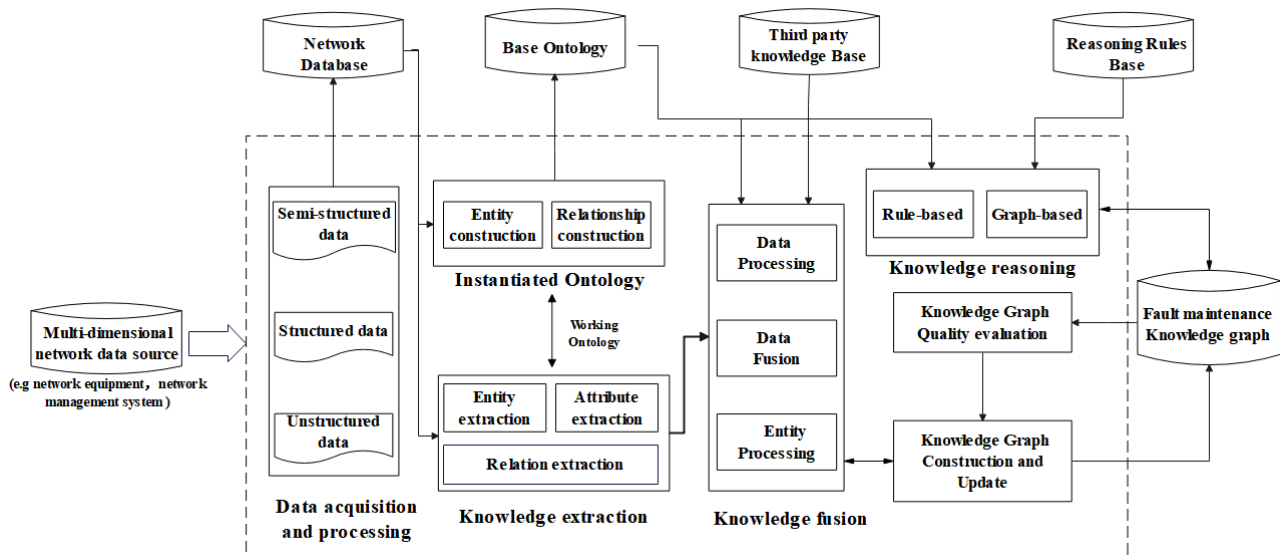


Figure 5-1: The main process of the network fault maintenance knowledge graph construction

An overview of building the fault maintenance knowledge graph is described below.

1) Data acquisition and processing

For data of interest, such as log and alarm data provided by the network, the system will regularly collect data, process the data (e.g. perform tasks such as data filtering, correlation, cleansing, and deduplication) and normalize the collected data (refer to [i.5]). After processing, the data is stored in the Network Database for further processing.

2) Ontology design and update

The Base Ontology is a set of ontologies that contain a starting ontology to work with. For example, ontologies defining information about network entities, people, and other relevant concepts could be used. These are then combined into a single starting ontology.

The Instantiated Ontology is used for two purposes. First, data and information that has been ingested and processed in step 1 is incorporated directly in the Instantiated Ontology if it is in a suitable form. If not, then it is first processed in the Working Ontology, which converts the data into entities, attributes, and relationships between entities, possibly using the information and/or data models defined in ETSI GS ENI 019 [i.6] as a guide. These entities, attributes, and relationships are then uploaded to the Instantiated Ontology, which verifies and integrates them, and uploads a new version of the Ontology to the Base Ontology and also to the Working Ontology. Once this process is complete, the Working Ontology is then used for further processing. This keeps a backup in the Instantiated Ontology in case of problems in further processing.

3) Knowledge extraction and knowledge fusion

Knowledge extraction is the secondary processing of data in the database, aiming to extract knowledge entities (i.e. the entities in the instantiated and working ontologies) and their relationships in the data, and add processed information to the knowledge graph.

The main tasks of knowledge fusion include three categories of measurements. Exemplary processing tasks of each category are provided.

- Data Processing
 - Tokenization transforms the text into smaller units called data tokens. Tokens can be words, punctuation marks, numbers, symbols, or any other meaningful elements of a text. This is used as the basis for many natural language processing tasks.
 - Lemmatization is a process of finding the base or root form of a word. For example, the words "running", "runs", and "ran" are all different forms of the word "run". This is used to normalize words for more complex tasks, such as named entity recognition and co-reference resolution.

- Data Annotation provides additional information to better describe the datum and its purpose and functionality. This is typically in the form of metadata attached to the datum.
 - Entity Processing
 - Named Entity Resolution is a process in Natural Language Processing that involves recognizing when two observations relate semantically to the same entity, despite possibly having been described differently. It also involves recognizing when two observations do not relate to the same entity, despite having been described similarly. Named Entity Resolution helps in standardizing entities and improving the accuracy of information extraction from text data.
 - Relation extraction is the task of identifying the relationships between entities. This is essential for understanding the meaning of the data.
 - Co-reference resolution is used to resolve ambiguities when extending knowledge graphs with new facts. It also aids in semantic integration, helping to model semantic relationships between different structures so that a coherent global view can be obtained.
 - Data Fusion
 - Data Alignment is a preprocessing step that ensures the collected data from different sources is in a format that can be effectively combined or fused. This process often involves the temporal alignment of multimedia data.
 - Semantic Processing determines the meaning of the data elements, the relationships between the data elements, and the context in which the data is collected.
 - Semantic data integration is the process of combining data from disparate sources into a single, unified dataset in a way that preserves the meaning of the data. This is done by understanding the semantics of the data, which includes the meaning of the data elements, the relationships between the data elements, and the context in which the data is collected.
 - Semantic Data Fusion combines the different data into a single unified dataset with common semantics. There are a number of different approaches for achieving this, including:
 - Feature-level fusion: This approach involves combining features from different data sources at the feature level. This can be done using a variety of techniques, such as averaging, weighted averaging, and principal component analysis.
 - Decision-level fusion: This approach involves making separate decisions based on each data source and then combining the decisions. This can be done using a variety of techniques, such as majority voting, weighted voting, and Dempster-Shafer theory.
 - Model-level fusion: This approach involves combining the models from different data sources to create a single, unified model. This can be done using a variety of techniques, such as ensemble learning and Bayesian inference.
 - Knowledge-based Fusion: This approach uses knowledge about the domain to fuse data. Knowledge-based fusion can be used to fuse data from sources that are not directly compatible. For example, a knowledge-based fusion system could be used to fuse data from a database and a set of expert rules to create a more complete and accurate view of a system.
- NOTE: It is recommended that multiple fusion approaches be used to provide more accurate results and ensure that varying semantics from each data source are taken into account.
- Define Data Fusion Rules: this defines a set of rules for choosing among the above approaches as well as handling conflicts and inconsistencies that arise during the fusion process.