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Experiential Networked Intelligence (ENI); Definition of data processing mechanisms

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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
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Foreword

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

Modal verbs terminology

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Introduction

The present document outlines a high-level reference framework that describes technical methods for producing high-quality actionable data efficiently and in a timely manner.

The organization of the present document is as follows:

- Clause 1 defines the scope of the present document.
- Clauses 2 and 3 provide informative references, terms, symbols and abbreviations.
- Clause 4 describes an overview of the data mechanism, including its motivation and challenges.
- Clause 5 defines components in the high-level framework of the data mechanism in terms of data acquiring and data processing.
- Clause 6 presents the data mechanisms in some example scenarios proposed in ETSI GR ENI 001 [i.1], Use Case specification.
- Clause 7 concludes possible contributions to other ENI group specifications of the present document.

Data Telemetry is used as an example for data mechanisms description and analysis.

1 Scope

The present document describes some technical methods to support data-driven intelligent network scenarios. The realization of intelligent networks depend on extracting value from Big Data using AI algorithms. Therefore, effective data acquisition, processing and management is extremely important as described in this context.

The present document covers the following aspects:

1) Data classification in terms of the data sources producing the data (e.g. network management system, network elements, servers, terminals and external environment data), data characteristics (e.g. configuration or sequential data), and data format.

2) Data operation including data collection, data storage, data processing, data sharing and data management:

   a) Data collection including description about collection modes (e.g. pull (query/request response) and push (publish/notify)), and data collection techniques, such as telemetry.

   b) Data storage recommendations.

   c) Data processing, including data cleansing and data correlation.

   d) Data sharing.

   e) Data management, including metadata management, data security management and data quality management.

3) Data acquisition and processing methods of selected use cases proposed in ETSI GR ENI 001 [i.1] for ENI systems executing intelligent tasks.

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 001 (V3.1.1): "Experiential Networked Intelligence (ENI); ENI use cases".

[i.2] ETSI GR ENI 004 (V3.1.1): "Experiential Networked Intelligence (ENI); Terminology for Main Concepts in ENI".

[i.3] ETSI GS ENI 005 (V2.1.1): "Experiential Networked Intelligence (ENI); System Architecture".

[i.4] IETF RFC 7011: "Specification of the IP Flow Information Export (IPFIX) Protocol for the Exchange of Flow Information".

[i.5] IETF RFC 7950: "The YANG 1.1 Data Modeling Language".

[i.6] IETF RFC 4656: "A One-way Active Measurement Protocol (OWAMP)".

[i.7] IETF RFC 5357: "A Two-Way Active Measurement Protocol (TWAMP)".

[i.8] IETF I-D.ietf-ippm-ioam-data-11: "Data Fields for In-situ OAM".

[i.9] IETF RFC 8321: "Alternate-Marking Method for Passive and Hybrid Performance Monitoring".

[i.10] IETF RFC 8889: "Multipoint Alternate Marking method for passive and hybrid performance monitoring".

[i.11] IETF RFC 7799: "Active and Passive Metrics and Methods (with Hybrid Types In-Between)".

[i.12] Recommendation ITU-T Y.1731: "OAM functions and mechanisms for Ethernet based networks".

[i.13] IETF RFC 6241: "Network Configuration Protocol (NETCONF)".

[i.14] IETF RFC 4271: "A Border Gateway Protocol 4 (BGP-4)".

[i.15] IETF RFC 7854: "BGP Monitoring Protocol (BMP)".

[i.16] IETF I-D.draft-kumar-rtgwg-grpc-protocol-00: "gRPC Protocol".

[i.17] IETF I.D.draft-zhou-ippm-enhanced-alternate-marking-05: "Enhanced Alternate Marking Method".

[i.18] IETF I.D.draft-song-ippm-postcard-based-telemetry-08: "Postcard-based On-Path Flow Data Telemetry using Packet Marking".

[i.19] IETF RFC 793: "Transmission Control Protocol (TCP)".

[i.20] IETF RFC 768: "User Datagram Protocol (UDP)".

[i.21] VNF Event Stream (VES).

NOTE: Available at https://wiki.opnfv.org/display/ves/VES+Home.

[i.22] IETF RFC 3416: "Version 2 of the Protocol Operations for the Simple Network Management Protocol (SNMP)".

[i.23] IETF RFC 959: "File Transport Protocol (FTP)".

[i.24] The Atlan Data wiki definition of structured data.

NOTE: Available at https://wiki.atlan.com/structured-data/.

[i.25] The Atlan Data wiki definition of unstructured data.

NOTE: Available at https://wiki.atlan.com/unstructured-data/.

[i.26] IETF RFC 4560: "Definitions of Managed Objects for Remote Ping, Traceroute, and Lookup Operations".

[i.27] Prometheus open source.

NOTE: Available at: https://prometheus.io/.

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.2], ETSI GS ENI 005 [i.3] and the following apply:

column-oriented database: database that organizes data by field

NOTE: This type of database keeps all of the data associated with a field next to each other in memory, and is optimized for online analytical processing. They are optimized for reading and computing on columnar data. Examples include Snowflake and BigQuery.

data lake: centralized storage repository that stores raw data that are in the form of structured, semi-structured and unstructured format

data mart: subset of a data warehouse focused on a particular line of business, department, or subject area

data warehouse: repository used to connect, analyse, and report on historical and current data from heterogeneous sources

NOTE: A data warehouse is designed for query and analysis as opposed to transaction processing. It analyses and reports on data from operational systems as used in decision-support systems.

hadoop distributed file system: distributed fault-tolerant file system that stores data on commodity machines and provides high throughput access

massively parallel processing: use of a large number of processing nodes that perform a set of coordinated tasks in parallel using a high-speed network

NOTE: The processing nodes typically are independent, and do not share memory, and typically each node runs its own instance of an operating system.

Prometheus: open-source systems monitoring and alerting toolkit

NOTE: This open source is originally built at SoundCloud. Since its inception in 2012, many companies and organizations have adopted Prometheus, and the project has a very active developer and user community. It is now a standalone open source project and maintained independently of any company. To emphasize this, and to clarify the project's governance structure, Prometheus joined the Cloud Native Computing Foundation in 2016 as the second hosted project, after Kubernetes.

protocol buffers (protobuf): language-neutral, platform-neutral, extensible mechanism for serializing structured data

reinforcement learning: See ETSI GR ENI 004 [i.2] and ETSI GS ENI 005 [i.3].

row-oriented database: database that organizes data by record

NOTE: This type of database keeps all of the data associated with a record next to each other in memory, and is optimized for online transaction processing. An example is MySQL.

semi-structured data: information that does not conform to a formal data model, but does have some organizational properties that define key data (e.g. tags) that enable data to be self-describing

software defined hardware: software programmable hardware that is able to be reconfigured at runtime to enable near ASIC performance without sacrificing programmability for data-intensive algorithms

structured data: information organized in a predetermined way (a fixed format, data model or schema) within a record or a file

NOTE 1: As defined in [i.24].

NOTE 2: Structured data enables all elements to be individually addressable, and conform to a data model.

unstructured data: information that does not have a pre-defined data model, and does not contain properties that provide any organization or structure to its elements

NOTE: Unstructured data needs to be processed in order to find information by domain-specific applications.

video stalling: process during the video playback, the video is paused and waits for the buffer due to dragging or other reasons

3.2 Symbols

Void.

3.3 Abbreviations

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

5G	Fifth Generation
AI	Artificial Intelligence
AS	Autonomous System
BGP	Border Gateway Protocol
BMP	BGP Monitoring Protocol
BSS	Business Support Systems
CPU	Central Processing Unit
CRM	Customer Relationship Management
EAM	Explicit Address Mapping
ENI	Experiential Networked Intelligence
FTP	File Transport Protocol
gNMI	gRPC Network Management Interface
IETF	Internet Engineering Task Force
IMS	Integrated Management System
IOAM	In-band OAM
IP	Internet Protocol
IPFIX	IP Flow Information eXport
IPFPM	IP Flow Performance Measurement
IPPM	IP Performance Metrics
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication standardization sector
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
MS	Monitoring System
NE	Network Element
NMS	Network Management System
OAM	Operation, Administration and Maintenance
OMC	Operations and Maintenance Centre
OSS	Operations Support Systems
OWAMP	One-Way Active Measurement Protocol
PBT	Postcard-Based Telemetry
QoS	Quality of Service
SDN	Software-Defined Networking
SDK	Software Development Kit
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
SQL	Structured Query Language
SR-IOV	Single Root I/O Virtualization
TCP	Transmission Control Protocol
TWAMP	Two-Way Active Measurement Protocol
UDP	User Datagram Protocol
VES	VNF Event Stream
VNF	Virtual Network Function
XML	Extensible Markup Language
YANG	Yet Another Next Generation

4 Overview

4.1 Background

Exploiting network data for intelligent network applications and use has been increasing in recent years. By combining AI and machine learning algorithms, network data is able to provide insights that help network operators better manage and optimize the network. Therefore, the quality of available sample data, for instance, time validity, diversity, volume, accuracy, plays an important role in learning from data. One challenge is that large amounts of data as well as data that meets the demands is able to be acquired. Additionally, the data collected from network equipments from different vendors varies in the aspect of name, format, calculation rules, etc. Thus a large amount of time is often be spent to do the data normalizing, cleansing, and engineering before those data could be used to train the model. This blocks the deployment of actionable decisions, which are meant to improve ENI System performance and User Experience.

The present document describes data acquisition, sharing and processing mechanisms, as well as supports for data privacy in AI-enabled network Operation, Administration and Management (OAM). The present document identifies the sources and data to be extracted, however it does not intend to explain how the mechanisms work, or how data is processed in order to became used. This could be addressed in a later release.

4.2 Data Precondition

Different types of data are able to be analysed only and interpreted correctly in particular contexts. The following are examples of some of the types of data that the present document focuses on.

Real-time data: Typically, network data has to be continually monitored and dynamically processed in real-time. Example processing includes filtering, correlation, and cleansing. This is typically down locally and then aggregated results are distributed for further processing.

Continuous data: In some cases, continuous data over a long time span is required for analysis or model training. For example, historical traffic data are used to predict future traffic trends. In general, the longer the time span, the more representative it is, but the larger the data volume. Therefore, a way of efficiently processing and managing continuous data is needed.

NOTE: More consideration on "historical data" will be described in a future version in a later release.

5 Data Mechanism

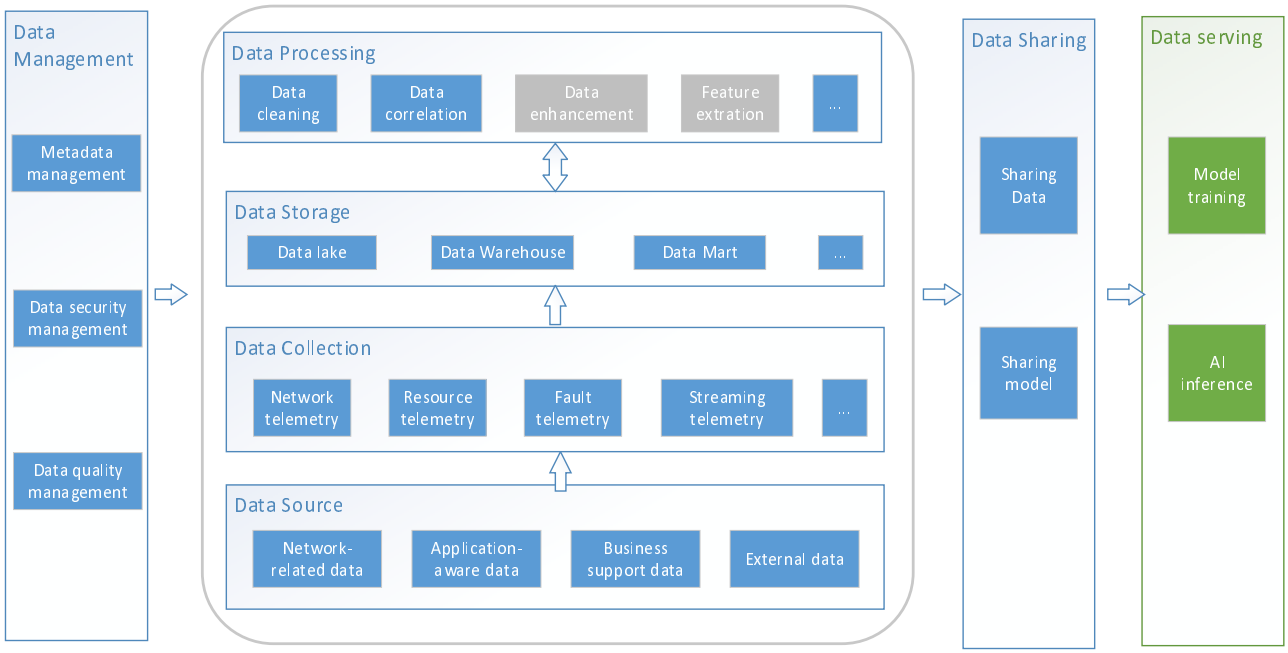
5.1 Introduction

5.1.1 Data Mechanism Overview

This clause defines components in a high-level overview for data acquisition and processing. Furthermore, this clause classifies different types of data in terms of their data sources, as well as describes data processing mechanisms, in order to support AI enabled network OAM and service management.

The Data Mechanism supports different data acquisition and processing mechanisms for data from different sources and for use by different network applications.

As shown in Figure 5-1, the data mechanism overview is able to be partitioned into the following components.



NOTE: The content in grey box will be described in a future version in a later release.

Figure 5-1: Data Mechanism Overview

The main components above are thoroughly described and explained in the next clauses. However, before doing that, some information will be provided on the data contents characteristics, i.e. on the types of data that are able to be used to classify data as well as on the parameters that encompass each type and the scenarios where they could be found.

Telemetry is a service/application related to the collection of measurements, statistics, or other related data at pre-determined points, and the subsequent and automatic transmission of those data to appropriate devices. It will be used throughout this clause as an example of data source in order to provide some practical application to the descriptions presented in the main text.

5.2 Data Characteristics

5.2.1 Configuration Data

Configuration data are used to identify the context in which measurements are made. Table 5-1 lists some examples of configuration data that are required to be made per-user, per-service telemetry measurements, see clause 5.4.1.

Table 5-1: Exemplary Configuration Data Characteristics

Configuration Data	Brief Description	Source	Scenario
Network device attribute information	Device ID, location, device model/version	Network Management Systems --> OSS	Network device alarm root cause analysis
Network device configuration information	Device IP, port, Vlan ID, IP Route Protocol	Network Management Systems	Intelligent traffic steering
Customer information	IMEI, IMSI, Terminal type, user name, user level (e.g. VIP user), register time, subscription service information	Network Management Systems --> BSS	Content Recommendation

5.2.2 Sequential Data

Sequential data are a series of data recorded in time order. Table 5-2 shows some examples of sequential data.

Table 5-2: Exemplary Temporal Data Characteristics

Sequential Data	Brief Description	Source	Scenario
Fault data	Alarm, log	Network Management Systems	Network device alarm root cause analysis
Performance data	CPU, memory, and I/O usage memory	Network infrastructure --> servers	KPI anomaly analysis
Network traffic data	Throughput, rate, delay	Network infrastructure --> switches, routers	Traffic prediction
External environment data	Temperature, humidity	External sources --> sensors	Device equipment energy saving

5.2.3 Data Format

Data is able to be classified into structured, semi-structured, and unstructured data formats.

Structured data is information organized in a predetermined way (a fixed format, data model or schema) within a record or a file [i.24]. Structured data enables all elements to be individually addressable, and conform to a data model. Table 5-3 shows some examples of structured data in the network.

Table 5-3: Exemplary Structured Data Characteristics

Structured Data	Brief Description	Source	Scenario
Relational Data	Data structured that adheres to a pre-defined data model	SQL database	Customer information

Semi-structured data is information that does not conform to a formal data model, but does have some organizational properties that define key data (e.g. tags) that enable data to be self-describing.

Table 5-4: Exemplary Semi-structured Data Characteristics

Semi-Structured Data	Brief Description	Source	Scenario
XML Data	Data that has some organizational properties	XML Data Store	Some types of Network Data

Unstructured data is information that does not have a pre-defined data model, and does not contain properties that provide any organization or structure to its elements. It will be pre-processed in order to find information by domain-specific applications [i.25]. Table 5-5 shows some examples of unstructured data in the network.

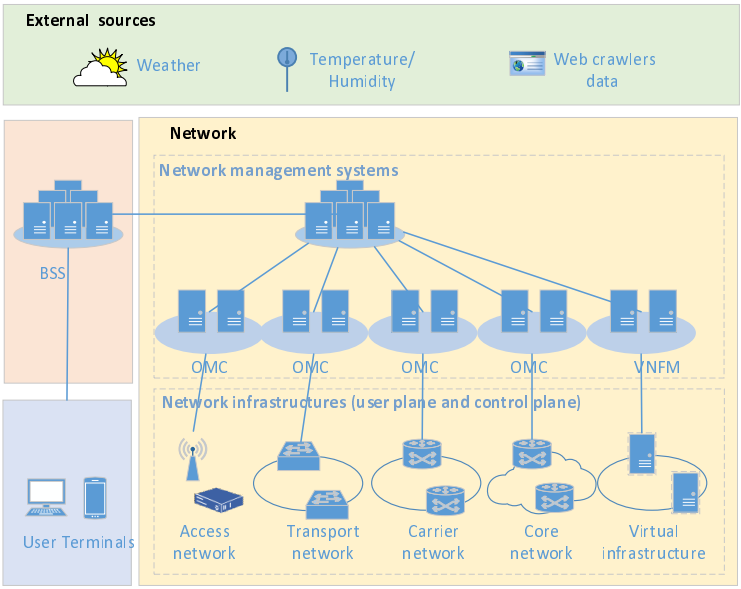
Table 5-5: Exemplary Unstructured Data Characteristics

Unstructured Data	Brief Description	Source	Scenario
Word®, PDF®, or Text Documents, Media Files	Data that does not have a pre-defined data model	BSS	Content (e.g. streaming media)

5.3 Data Source

5.3.1 Introduction

This clause describes the Data Source components, e.g. network management system, network elements, servers, terminals, external environment data, etc., see Figure 5-2.



NOTE 1: Figure 5-2 should also contain an application domain that was not represented for the sake of clarity. That application-aware data includes user's experience data, e.g. initial buffing delay, freezing when a user is watching video.
NOTE 2: User devices will be described in a later release.

Figure 5-2: Data Sources Categories, see notes 1 and 2

The Data Source components have been categorized as follows:

Network-related data: includes data from user plane network infrastructure elements (e.g. base stations, routers, switches and virtual infrastructure) placed in the different segments of the network (e.g. access, transport carrier, core and cloud), control plane network elements (e.g. Software-Defined Networking (SDN) controllers)), as well as all levels of network management systems (e.g. OMC). The way of collecting data from network elements and network management systems will be described in the next clause.

Business support data: includes user management data, e.g. user name, user level (e.g. VIP user), register time, subscription service information, accounting data.

External data: auxiliary data that is generated outside the network or is unrelated to network behaviour but still relevant for understanding network operation state, including physical sensors that provide environment information (e.g. weather, temperature, humidity), external web/app-based information (e.g. web crawler that provides online news) and data derived from external software tools.

5.4 Data Collection

5.4.1 Introduction

Data Collection includes gathering and measuring data. The data gathered includes traffic by mirror, log, etc., whereas data measuring uses specific protocols which are examples of Telemetry, such as OWAMP [i.6], TWAMP [i.7], Traceroute [i.26] or IOAM [i.8].

5.4.2 Data Acquisition Modes

Data Collection is described in three modes, as follows:

- **Pull** is a mode where data is requested by a consumer and responded to by a producer.
- **Push** is a mode where data is sent by a producer to a customer.

- **Publish-Subscribe or Pub-Sub** is a messaging pattern where publishers of data are decoupled from subscribers of data. In other words, publishers do not send messages to specific entities, but rather, send messages to a pre-defined set of categories. Similarly, subscribers express interest in a set of categories, and have no knowledge of which publishers has delivered the data.

5.4.3 Data Collection Techniques

5.4.3.1 Introduction

Different types of network-related data could be collected during the telemetry service/application process execution. Those different types of data could be carried out by different protocols associated with different types of connection, e.g. the different functional planes are usually used to describe and deploy different services/applications by existing systems. In the following as an example, only the forwarding/user plane, the control plane, and the management plane are used to describe the data that could be collected in protocols running on them. The next clause deals with data extracted and carried out in those protocols in the above functional planes. The clause after that deals with specific data used to perform the telemetry service/application.

NOTE: The term user plane is applicable only to mobile networks. Forwarding plane (a.k.a "data plane") that could be used in other networks.

5.4.3.2 Data carried out in functional planes protocols

5.4.3.2.1 Data carried out in the Forwarding/User Plane

On the forwarding /user plane, the main function of devices is traffic processing and forwarding. Various data objects (e.g. packet loss, packet received timestamp, queue status) could be collected from various network elements (e.g. routers, switches) as a result of the forwarding process. Various telemetry data could be exported from forwarding chips or line cards through making use of specific tools, such as the IPFIX protocol [i.4].

Examples of monitoring and collecting data from these objects include, for example, packet-level monitoring that could provide precise information for calculating statistics such as the instantaneous bitrate, packet loss, or round-trip latency experienced by individual flows.

According to the categorization specified in IETF RFC 7799 [i.11], techniques of forwarding plane telemetry could be divided into active, passive and hybrid methods. Usually, the IPFIX protocol (IETF RFC 7011 [i.4]) and traffic mirror are considered as passive methods, which are based on observations of an unmodified packet stream. On the other hand, the active methods include, One-way Active Measurement Protocol (OWAMP) IETF RFC 4656 [i.6] and Two-Way Active Measurement Protocol (TWAMP) IETF RFC 5357 [i.7], which generates packet streams as the basis of measurement. The hybrid methods include in-situ Operation, Administration and Maintenance (OAM) (I-D.ietf-ippm-ioam-data [i.8]), IP Flow Performance Measurement (IPFPM, IETF RFC 8321 [i.9]) and Multipoint Alternate Marking (I-D.ietf-ippm-multipoint-alt-mark [i.10]) which augments or modifies the stream of interest to collect metrics.

5.4.3.2.2 Data carried out in the Control Plane

The main purpose of data acquisition in the control plane is to monitor the health of different network protocols. It is beneficial for detecting, localizing and predicting network issues/events through keeping track of the running status of protocols. Traditionally, approaches for control plane Key Performance Indicator (KPI) measurement include protocols such as PING for testing the reachability of a host in an IP network, Traceroute for displaying the path and measuring transit delays, and Recommendation ITU-T Y.1731 [i.12] for measurement of Ethernet frame delay, frame delay variation, frame loss, and frame throughput specified by the ITU Telecommunication standardization sector (ITU-T), which only measure the KPIs but do not reflect the actual running status of network protocols.

The control plane telemetry objects include control protocol or signalling objects, which could be exported from, for example, the main control Central Processing Unit (CPU). For example, the Border Gateway Protocol (BGP) [i.14] monitoring protocol (BMP [i.15]) could be used for monitoring the BGP routes to enable security analysis, Autonomous System (AS) analysis, PING, Traceroute [i.26] that could be used to determine the round-trip delay in communicating with the host and packet loss, etc. Ping uses a series of Internet Control Message Protocol (ICMP) Echo message to determine whether a remote host is active or inactive, whereas Traceroute shows an actual path.

5.4.3.2.3 Data carried out in the Management Plane

The main functions associated to the Management plane are monitoring, configuration, and maintenance of devices. Information such as performance data, network logging data, network warning data, and network state data is collected from the management plane, which interacts with the Network Management System (NMS). Some legacy protocols (e.g. Simple Network Management Protocol (SNMP) and Syslog), are widely used in the management plane telemetry, where configuration and operation state could be exported from main control CPU. In addition, some network management protocols (e.g. gRPC [i.16] Network Management Interface (gNMI) [i.22], Network Configuration Protocol (NETCONF) [i.13], YANG Push [i.5]) have the ability to request telemetry information.

5.4.3.3 Specific data used to deploy telemetry

5.4.3.3.1 Network Telemetry

An ENI System uses Big data analytics and machine learning technologies to analyse and produce actionable decisions from network telemetry data for improved network operator experience. A single-sourced and static data acquisition mechanism could not meet the volume, velocity, variety, and other requirements of these technologies. It is desirable to have a framework that integrates multiple telemetry and data collection approaches. This allows flexible combinations for different telemetry data acquisition from different applications.

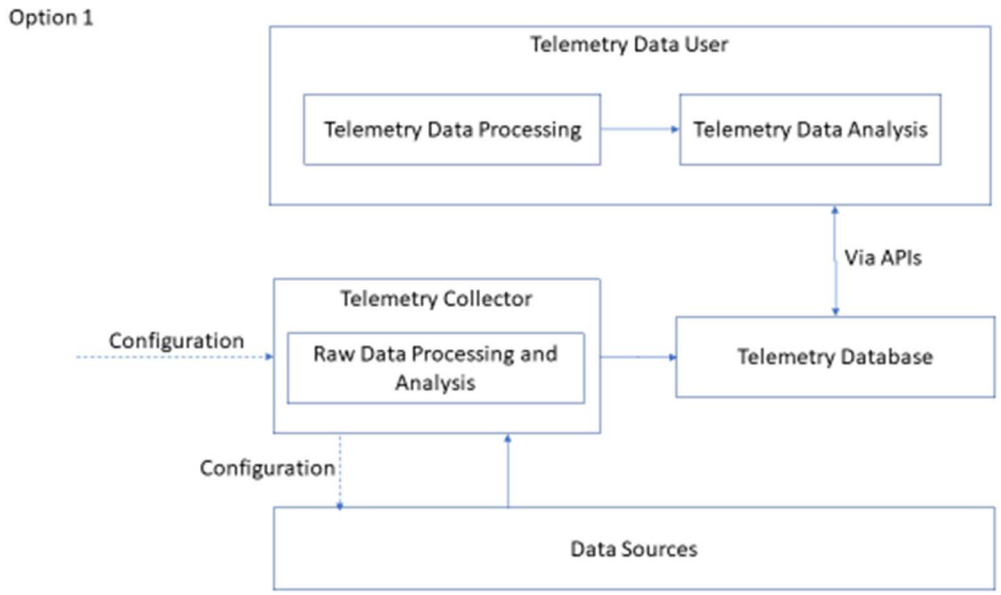


Figure 5-3a: Components of Network Telemetry framework, API option

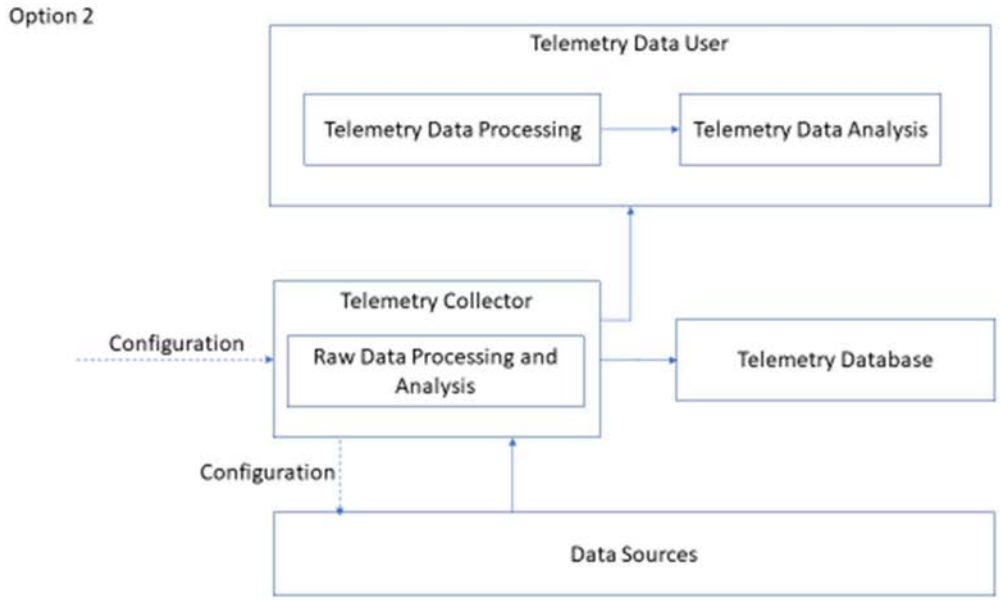


Figure 5-3b: Components of Network Telemetry framework, Push Option

The components of a network telemetry framework shown in figures 5-3a and 5-3b. There are two options for Telemetry Data User to get data:

1) deliver the data from Telemetry Collector directly; or

2) get data from Telemetry Database via APIs.

The components are defined as follows:

- **Telemetry Data User:** subscribe for the telemetry data, determine the telemetry data source and determine what types of telemetry the system needs. The Telemetry Data Processing and Analysis is responsible for analysing the feedback data from network devices. Based on data analysis results, further data requirements could be issued. Telemetry Data User could be part of network Operator Support System.

- **Telemetry Collector:** collect raw telemetry data, measurement metrics, such as delay, loss rate and jitter, could be generated and processed through In-situ OAM (IOAM) [i.8], Enhanced Alternate Marking (EAM) [i.17], Postcard- Based Telemetry (PBT) [i.18], IP Flow Performance Measurement IPFPM [i.9], etc. The Raw Data Processing and Analysis performs any filtering, aggregation, anonymization, and other functions. The Raw Data Processing and Analysis encompasses two functions processing on the raw data and analysis on formatted data. The Raw Data Processing could include filtering, aggregation and anonymization.

- **Telemetry database:** repository used to store the data collected from data sources.

- **Data Source:** provides the requested data to be captured, processed, and formatted in the network devices. For example, for the forwarding plane telemetry, the objects could include flow, packet and path and as an implementation option data encoding.

- **Configuration:** is expected to come from an External Source for example from other ENI or OSS fuctions. The OSS could include the Telemetry Data User hence there are two options for the input of the Configuration.

5.4.3.3.2 Resource Telemetry

This clause describes telemetry techniques for data coming from across various available resources.

In a lifecycle managed infrastructure, resources generate multiple data sets for machine learning and Big Data analytics-based systems. For data collection, extraction and subscription mechanisms to effectively retrieve resource telemetry, it is crucial to extract data from various sources of resource telemetry available across the infrastructure. Communication across the infrastructure resources is crucial for efficient operations, where correlation between the collected data across these resources is needed.

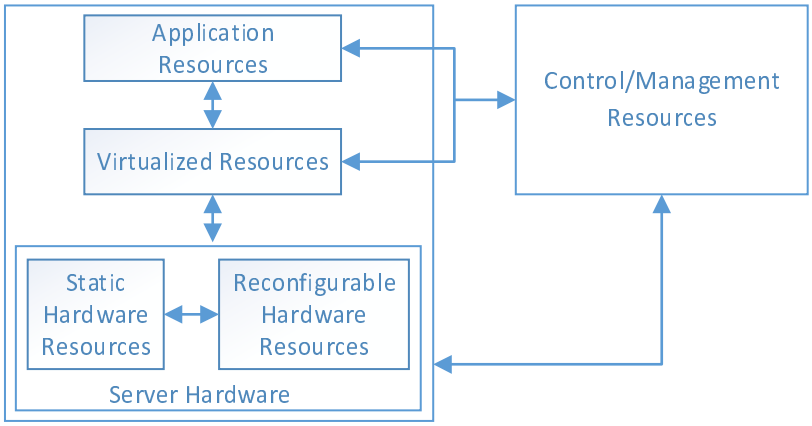


Figure 5-4: Various infrastructure resources that generate telemetry data

Below are the four resource descriptions for the forwarding (user) plane within the a network device:

- **Data Collection from non-reconfigurable Hardware Resources:** telemetry agents that extract data from the hardware resources of a network device need to be efficient, performant and sensitive to latency in order to obtain the desired set of hardware metrics. To obtain actionable insights from static hardware resources requires the collector and analytics agent to be sensitive to performance. Use cases like power savings, last level cache management, etc., that impact network packet latency heavily rely on key hardware resource telemetry to be consumed and analyzed for actionable insights by analytics systems trough the use of machine learning algorithms which digest the telemetry. Event monitoring tools enable action to be taken on one or more of a series of points. These types of tools typically provide streaming data that could optionally be pre-processed (e.g. aggregated, correlated, or have calculations done on them). Another example would be a system that provides reports on memory and network usage, disk usage, and other counter-orientated statistics by polling at a specified time interval. In addition, event traces could also be provided.

NOTE: Agentless Telemetry is for study in a later release.

- **Data Collection from Reconfigurable Hardware Resources:** hardware accelerators, software defined hardware and real-time reconfigurable hardware are increasingly common across software defined infrastructure. Data collection from these resources requires the collectors to be sensitive to changes in hardware configuration, which could be conveyed in matadata, and export out the data in real time in order to facilitate actionable insights. Specifications for hardware such as the Intelligent Platform Management Interface could provide always available and real-time monitoring capabilities.

- **Data Collection from Virtualized Resources:** data extracted from network devices like virtual switches, virtual routers, virtual machines, etc., could provide key telemetry to feed into machine learning algorithms and Big Data analytics engines.

- **Data Collection from Application Resource:** applications that utilize hardware and virtual resources in the network are necessary to expose relevant telemetry for exporting to data storage mechanisms. Application monitoring tools are crucial to gather relevant telemetry. Protocols such as VNF Event Stream (VES) [i.21] help to export the metrics in standardized formats.

- **Data Collection from Control and Management Resources:** control and management also interact with network devices in order to accomplish the functionalities that are associated to them. However, in this case, these functionalities are not relevant per se, rather the data that could be collected from the protocols that carry it. Regarding those protocols as data resources it has to be considered that latency sensitive environments heavily rely on decision time spent by analytics algorithms and enforcement time. Moreover, relevant interfaces into control and management layers help to extract important data about state and performance of these layers. Most environments have control and management resources allocated separately.

Analytics components and artificial intelligence functions need to be aware of the interaction between various resources and resource telemetry involved. The nature of interactions between various types of resources are described below:

- **Application and Virtualized Resources Interaction:** network applications, deployed either in cloud native model or in virtual appliance model, need tight interaction and integration with virtual instances such as virtual switch, virtual router, virtual firewall, virtual load balancer, etc. Virtual resources heavily impact performance of software applications as software resources rely on virtualization layer to access various hardware resources and enforcement of control and management decisions.

- **Virtualized and Hardware Resources Interaction:** hypervisor plays an important role to provide tight integration between virtualized resources and various types of hardware resources. Leveraging telemetry from interactions across these two layers helps to provide secure and scalable solutions across various infrastructure management use cases. These interactions are often exposed via kernel calls, hypervisor metrics, kernel networking subsystem, etc.

- **Static Hardware and Reconfigurable Hardware Resources Interaction:** offloading the application functions at run time to reconfigurable hardware resources is often done via applications utilizing static hardware. Density and nature of interactions between these two types of hardware resources could help to uncover bottlenecks across infrastructure performance and application deployment, which could be often captured via monitoring traffic and memory sub-system accesses among these two components.

- **Software and Control/Management Resource Interaction:** life cycle management of applications utilize telemetry from software applications for control and management layers to infer and enforce appropriate decisions. It is imperative that software resources produce appropriate telemetry in a format that is best consumable by big data type agents in the control and management components.

- **Virtualized and Control/Management Resource Interaction:** telemetry from virtual switches and routers, virtual machines, etc., help control and management layers to obtain a snapshot of scale, performance and security of the infrastructure. Decisions to leverage Single Root I/O Virtualization (SR-IOV) or leverage accelerators for latency sensitive applications, are possible while consuming and assimilating telemetry from across virtualized layers.

- **Hardware and Control/Management Resource Interaction:** with advent of software defined hardware infrastructure, interaction between these two layers is crucial to help latency sensitive applications appropriate hardware configurations. Decisions to reconfigure hardware settings (such as for Field Programmable Gate Arrays (FPGAs), run time adjustment of hardware resources allocated to virtualized and software layers, hardware bandwidth control, etc. in the control layer requiring the management layer to consume the appropriate hardware telemetry.

5.4.3.3.3 Fault Telemetry

In a lifecycle managed infrastructure, data extracted from fault telemetry plays a crucial role in the detection and isolation of various faults across the lifecycle process stack. The life cycle of faults and fault processing in general could be broadly represented as indicated in Figure 5-5.

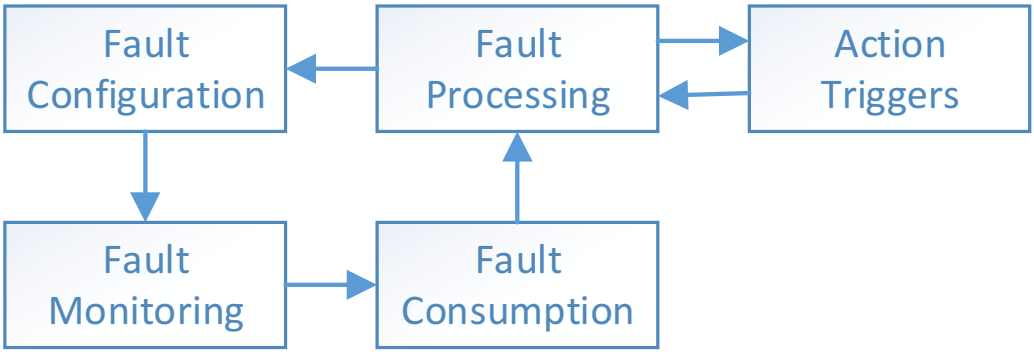


Figure 5-5: Various stages of a Fault Processing lifecycle

The five components of the fault telemetry lifecycle are defined as follows:

- **Fault configuration:** the nature of the infrastructure and applications deployed dictate what types of fault monitoring methods should be configured. This includes defining where a fault could be detected, how it is detected, and the permissions assigned to view faults.
- **Fault Monitoring:** faults could be broadly classified, based on the entity generating the faults, as:
  - Hardware faults, e.g. switch, and router faults, including routers programmed as firewalls
  - Application faults
  - Virtualization faults (incudes hypervisor faults)
  - Service faults
  - Communication faults

  These faults could be generated across various data sources as described in Figure 5-5 and are consumed by appropriate agents.

NOTE: Agentless approaches will be considered in a future release.

- **Fault Consumption:** based on the nature of the fault, a software entity is required to consume the fault. Software entities could be generic or specific in nature (e.g. a tool that responds to SNMP [i.22] or YANG [i.5] data versus a tool that is written specifically for a particular type of fault monitoring application). General purpose monitoring software such as Prometheus [i.27] uses a time series database to capture and produce various alarms, notifications, etc.
- **Fault Processing:** data typically needs to be normalized before it is analysed. The normalization is similar in nature to that described in ETSI GS ENI 005 [i.3]. A variety of mechanisms could be employed to fine tuning fault detection and classification by using Machine Learning and other AI algorithms.
- **Action Triggers:** this is a consequential action taken or to be taken by external entities (i.e. NMSs or EMSs governance) in order to address the fault and mark the fault as resolved.

Fault information and fault telemetry results could be exposed via well know outputs, where the most commonly used are alarms, events, notifications, log messages and fault or failure reports.

5.4.3.3.4 Streaming Telemetry

Modern cloud native deployments using microservices based platforms require telemetry and observation to be adapted to scale to the needs of microservices. Traditional telemetry mechanisms that generate data every 5 to 10 minutes are no longer applicable or scalable. Streaming telemetry is a modern method deployed in the cloud native context where microservices use push based mechanisms that continuously stream data. Network telemetry could leverage streaming telemetry by using existing data models such as YANG [i.5], OpenMetrics, etc., in order to enable a programmatic way to process and act on data in real time. Streaming telemetry frameworks provide a highly scalable mechanism for generating and consuming telemetry data sets that could be queried for analysis and help take appropriate actions in real-time automation.

5.5 Hierarchical data storage

This clause provides recommendations for the transformation process of different types of data, including raw data, feature data, training data and model data.

Different storage methods are used for different applications of data (e.g. data size, data popularity). Figure 5-6 shows these processes that transform data of one type to data of another type within a data storage hierarchy.

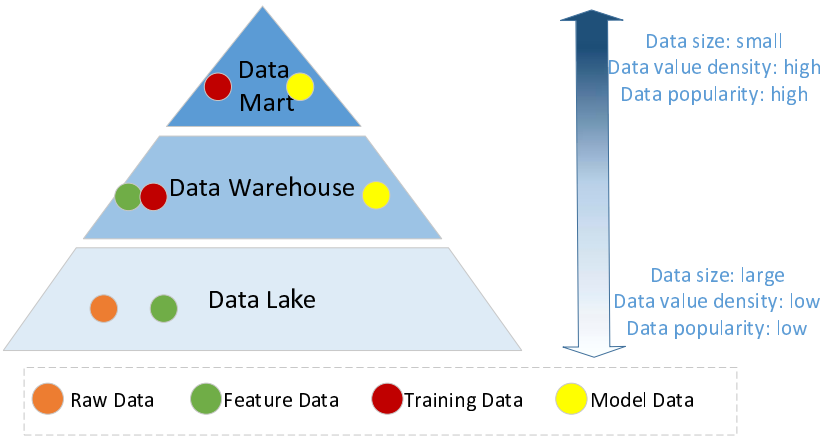


Figure 5-6: Data Usage Hierarchy

Figure 5-6 also shows a hierarchy of transformations on data to make it usable for machine learning features as training data sets. Also, transformations of training data into actual model data sets are expected.

Raw data: this includes all types of data that is of interest for producing high-quality actionable data. Examples include log files, raw traffic data, and service data. Knowledge and metadata are stored typically by the software entity performing the transformation from raw data into feature data to guide the transformation process. A large amount of raw data could create little value. Therefore, raw data is suggested to be stored in Data Lake.

Feature data: features are a component of an observation and are constituted by a set of attributes of data instances (e.g. the column of data in a relational database). Feature selection is the task of selecting which features to include in datasets [i.3]. Features could be extracted from raw data by means of e.g. data cleaning. Feature data is usually of high quality and used for analysis. Therefore, feature data is suggested to be stored in Data Lake or Data Warehouse. There are certain specific processing procedures to clean raw data and form feature data.

Training dataset: a training dataset is built by choosing a set of examples that fit the parameters of the model that will be used. Once a fitted model is obtained, a **validation dataset** is created. This enables the fitted model to be evaluated, and provides an opportunity to tune hyperparameters (i.e. the process of training models is the process of tuning hyperparameters). A **test dataset** could also be created; this is a dataset that is used to assess the performance of the model independently from the training dataset. Therefore, training data is suggested to be stored in Data Warehouse or Data Mart.

Model data: after model training, a model used by the selected algorithm is ready for use on real-world data in order to classify data and/or to make predictions. Model data is usually rarely written and read frequently. Therefore, model data is suggested to be stored in Data Warehouse or Data Mart.

In addition, deploying data, a data type not mentioned in Figure 5-6, is generated when models are deployed and used by selected algorithms. Deploying data includes the configuration data, the interface data, interactive data, etc. It is suggested that this type of data is stored with Meta Database or Config Database.

5.6 Data Processing

5.6.1 Data Correlation

AI applications use a broad range of data from multiple domains. Analysis of cross-domain data provides better insights and a better and deeper understanding on the usage of how the system is operating. More data means more correlation, which leads to a better training model.

Data Correlation exemplary scenarios are described below:

- **Scenario #1: Correlate data from different geographic locations:** The geographic locations are able to be classified according to different granularity, including different provinces, different cities, and different cells. For example, the need to collect traffic data from different locations and combine it as training data, due to diversified traffic patterns, is important for creating a generalized model.

- **Scenario #2: Correlate data from different network domains:** An end-to-end service typically spans multiple network domains/segments, including access network, transmission network, core network, etc. Important KQIs such as end-to-end service quality and availability need to be trained using data from different domains.

- **Scenario #3: Correlate data from different professional systems:** Correlating data from different data sources that are external to the network, but relevant to goals that the network is trying to achieve, also helps the service provider to achieve a more targeted model. Examples include data from OSS, BSS, and CRM systems.

5.6.2 Data Cleansing

Data cleansing is the process of detecting and correcting corrupt, inaccurate, incorrect, incomplete, irrelevant, or duplicated data. It produces consistent and well-formatted data for analysis, and endeavours to maximize the accuracy of the data.

Table 5-6: Data Cleansing process

Purpose	Problems	How to detect	How to process
Data accuracy	Abnormal data	Deviation analysis by using rule libraries	Edit data based on the type of abnormality
Data completeness	Incomplete data	Missing or null values (see note)	Add the missing information by inference from other known stored values. (see note)
Data measurement	Different data measurement methods	(see note)	(see note)
Data consistency	Different data formats	(see note)	(see note)
Data validity	data format checking	(see note)	(see note)
Data relevance	Evaluation of context awareness data	(see note)	(see note)
NOTE: This will be completed in a future release. Some evaluation of the pros & cons of showing the information content in a tabular form will be performed.			

5.7 Data Sharing

Data sharing is a process where the data provider shares its data with a data consumer.

Based on the content of the shared data different sharing methods are used, for instance there are two types of data sharing that could be used:

a) the data provider shares the data with the data consumer;

b) the data provider shares the AI model or algorithm with the data consumer.

Examples of data formatting mechanisms in protocols are shown as follows, depending on types of data:

a) Subscription procedure data sharing (like subscribe/notify) could be based on formats for example Protobuf or JSON.

b) Periodic transmission data sharing uses File Transport Protocol (FTP) [i.23] to transmit static data to receiver in the format of file or table.

c) Request/response data sharing procedures encompasses transmission by the provider of small volumes of data: where a response follows a single request query. In this case, the format of JSON/XML generally is used.

For AI model or algorithm sharing, the shared model could use a supervised or semi-supervised algorithm. In the unsupervised learning case only the AI algorithm could be shared.

5.8 Data Management

5.8.1 Overview

Data management consists of metadata management, data security management and data quality management.

5.8.2 Metadata Management

Metadata management is the set of processes that ensure proper creation, storage, integration, and control to support the associated usage of metadata. In particular, it consists of rules, guidelines, or best practices in applying metadata to data and behaviour. The process of integration means that data could be provided as a service in an integrated way, while, the process of control means that who is able to decide where and how to use the data.

5.8.3 Data Security Management

Data security management includes the planning, development, and execution of security policies and procedures to provide proper authentication, authorization, access, and auditing of data, information assets, encryption, accounting, key management, data erasure and vulnerability assessment. It consists of definition of data security policy, access control of data security and auditing of data security.

NOTE: This topic will be expanded in a future release.

5.8.4 Data Quality Management

Data quality management is a set of processes that maximize the customer uniqueness, consistency, and completeness of data (e.g. product and service data). It involves Data Governance, Master Data Management, Digital Asset Management, and other disciplines.

Data quality analysis analyses and evaluates the data quality of a data set to determine if measured data is meeting the SLOs of their SLA.

6 Example Scenarios to Illustrate Data Mechanisms

6.1 AI-enabled Traffic Classification Use Case

6.1.1 Introduction

Network traffic classification plays an important role in network operation and management, which supports numerous network closed-loop control activities in terms of network security, traffic engineering and Quality of Service (QoS). Traditional methods, such as port-based technique and payload-based technique, are inefficient and even fail to classify some types of network traffic, due to the increasing proportion of encapsulated traffic and enterprise private methods. Therefore, various techniques based on AI algorithms (e.g. pure machine learning) are used when training the algorithm to classify some types of network traffic. The training data set is composed of data stream features or extracted packet features with specific classification labels.

6.1.2 Data Acquisition

For the purpose of network traffic classification, the ENI System could collect the information as listed in Table 6-1.

Table 6-1: Data collected by ENI for network fault root-cause analysis and intelligent recovery

Information	Source	Characteristics	Data Format
Network Traffic data	Forwarding plane -->switches/routers	IP, port, packet length, inter arrival packet time, etc. extracted from TCP/UDP flows. See note 1.	See note 2.
NOTE 1: The indicated protocols are meant to be an example only within the use case. NOTE 2: The contents of this column will be addressed in a future release.			

6.1.3 Data Processing for traffic classification

This clause describes data processing procedures are performed in a sequential process within the ENI System as explained in the following steps, related to cleaning and labelling respectively:

1) Initially the data needs to be cleaned before it is available for processing traffic classification One or more packets could be lost during transmission. So some TCP [i.19]/UDP [i.20] flows could be incomplete. These flows that lack many packets or lack key packets (e.g. initial TCP 3-way handshake packets) are not recommended for model training or inference, and removed from the data set when they are proved to contain erroneous data. In addition, TCP flows could contain retransmission packets. Retransmission packets are recommended to be retained and some retransmission related information (e.g. retransmission packet numbers) should also be considered.

2) Secondly the cleaned data needs to be labelled for processing within traffic classification If supervised learning algorithms (e.g. Random Forests, Convolutional Neural Network) are applied for traffic classifier training, traffic data should be labelled. One way is to label the traffic types by analysing features (e.g. IP, special signatures in the packet payload). Another way is to assign labels to designated network traffic that is captured from network interfaces according to predefined rules, see note below.

There are differences between classifying traffic using packet payloads, host behaviour, and flow features. This use case uses traffic features to classify the type of traffic with a pre-defined recipe.

NOTE: These topics will be expanded in a future release, including labelling of traffic data for supervised learning.

6.2 Network Fault Root-Cause Analysis and Intelligent Recovery Use Case

6.2.1 Introduction

Network fault root-cause analysis and intelligent recovery is an important use case for the ENI System.

Traditional network fault location and repair need manual processing, which typically has high cost, low efficiency and long implementation timer. Applying a machine learning algorithm to network fault root-cause analysis and intelligent recovery could become a more effective solution, which shortens the time for fault recovery and improves the efficiency of network maintenance. When faults occur, AI algorithms (e.g. Knowledge Graph, Reinforcement Learning) are used to calculate the fault self-recovery policy with alarms data, network topology data, network service data collected from the Monitoring System (MS). The fault self-recovery operation is then delivered to network through a multi-vendor command platform. Self-recoverable faults could be quickly recovered and do not affect the user experience. If a fault could not be rectified, accurate diagnosis is able to be performed to locate the root cause (e.g. by using Big Data Mining Algorithms, Deep Learning Algorithms) thus helping engineers to quickly rectify the fault.

6.2.2 Data Acquisition

For the purpose of this Use case, the ENI System could collect the information as listed in Table 6-2.

Table 6-2: Data collected by ENI for network fault root-cause analysis and intelligent recovery

Information	Source	Characteristics	File Format
Network Element data (NE data)	IMS, see note.	NE name, NE type, NE IP address, physical location, running status, subnet, LSR ID	See note.
Link data	IMS	Alarm level, link name, link type, source network element, source network element Internet Protocol (IP), source port, source port IP, destination network element, destination network element IP, destination port, destination port IP, link rate, creation time	See note.
Tunnel data	IMS	Tunnel name, operation status, alarm status, enabling status, source node, destination node, creation time, tunnel ID, tunnel type	See note.
Alarm data	IMS	Log serial number, Network Element Name, object ID, NE type, NE sub equipment, NE name, equipment alarm serial number, alarm module, alarm type, alarm level, alarm status, occurrence time, confirmation time, clearing time, positioning information	See note.
NOTE: The contents of this column will be addressed in a future release.			

NOTE: IMS refers to the Information Monitoring System that monitors the real-time network alarms and dispatches the alarms data and network infrastructure data (e.g. network element data, network topology data, network service data) to the ENI System.

6.2.3 Data Processing

Like for other Use Cases this clause also describes data processing procedures supporting analysis in the ENI System, e.g. data storage, data filtering, data cleansing, data sharing, etc.:

1) Users need to save data that belong to the same data source with strong data correlation to that data source.

2) Alarm data cleaning and reordering. The original alarm log data contains a large number of alarm logs with the same name at the same time of the same node. For example, if data mining is used, this part of duplicated data has a great impact on the effect of the associated use of rule mining. Independently of the choice of the method, data mining or otherwise, this part of data is cleaned out and only kept in a record with the smallest serial number (the earliest occurrence time) in the equipment log. In addition, the sequence of the gateway log serial number and the device log serial number is inconsistent, which leads to the wrong rules (e.g. if mining is used), while the device log serial number is more accurate. Therefore, the alarm log of the same device is rearranged according to the device log serial number to ensure that the gateway log serial number could accurately reflect the sequence of the alarm log on the same device.

3) Compress the repeated data from frequent alarms, the display of the frequency. The alarms with high frequency need to be taken into account by operation and maintenance. Frequent re-occurrence could give a measure as to how important or severe the alarm is considered.

6.3 Intelligent Service Experience Evaluation Use Case

6.3.1 Introduction

It is important for operators to evaluate the user's service experience based on the network data. According to the network data, operators could find bad user's service experience and solve problems quickly. However, the traditional service quality evaluation methods based on predefined or empirical functions are sometimes not able to reflect real user's service experience in realtime, essentially for video transmission. Therefore, an AI algorithm is applied to train an evaluation model which represents the non-linear relationship between the transmission parameters and user's service experience. The training set includes network data and user's service experience data, and the latter is used as labels. In Table 6-3, the training data acquisition is shown. The service quality data acquisition could be performed by one of two options:

1) though a 3rd party service as defined in the 5G network case; or

2) by using the SDK service of client.

6.3.2 Data Acquisition

For the purpose of Intelligent Network Service Experience evaluation, the ENI System could collect the information as listed in Table 6-3.

Table 6-3: Data collected by ENI for service experience evaluation

Information	Source	Characteristics	File Format
Network data	Forwarding plane-->switches	TCP RTT, TCP retransmission rate, etc. See note 1.	See note 2.
Service quality data	1) through the third-party service open interface that is defined in the 5G network and oriented to the third-party Application Function (AF) 2) through the built-in Software Development Kit (SDK) of the third-party service client	initial buffering latency, video stalling duration, the number of video stalling events, etc.	See note 2.
NOTE 1: See next clause 6.3.3. NOTE 2: The contents of this column will be addressed in a future release.			

6.3.3 Data Processing

As for the other use cases, this clause describes data processing procedures supporting analysis in the ENI System:

1) A large amount of network data is generated when users access network. The fields of network data include e.g. TCP RTT, and TCP retransmission rate. Regarding the situation where large RTT and retransmission happens the service experience of the user is degraded. In some cases, fields of network data acquired by operators could be missing and that translates in service experience degradation. Also in other cases, fields of network data acquired by operators could be missing, so that this data could not be used directly in AI model training or inference. In order to increase the quality of the overall network data set, data addition and data cleaning techniques are applied to improve Training and Inference. In order to solve this, the deletion of network data entries that have too many fields could take place. Where entries are lost the missing data is filled in, if possible.

2) In order to create a training data set, user's service experience data should be associated with network data belonging to the same service session. User's service experience data includes initial buffing delay and video stalling. It equals to labels and reflects whether the quality is good or bad.

7 Recommendations

The present document describes some technical methods to support data-driven intelligent network scenarios. The extraction of data and its treatment is a crucial aspect regarding the realization of intelligent networks. It assumes a fundamental role in the performance of every AI-based system, in particular to ensure that the appropriate data is collected and processed accordingly. Ingested data could be used both for network operations as well as model training. More data, and in particular more quality data, means better knowledge to feed the system during the training process, and better chances to improve its performance.

That is why the data mechanisms analysed in the present document, i.e. data acquisition, storage, processing, sharing and management, become so relevant for the creation of proposals for ETSI GS ENI 005 [i.3]. The results of the investigation are applied to the standard specification.

In particular, the present document enriches the Data Ingestion Functional Block and the Normalization Functional Block of the ENI Reference System Architecture ETSI GS ENI 005 [i.3] by describing some technologies inside these two FBs with more detail. Based on the output of this study, some normative work for ETSI GS ENI 005 [i.3] could be found as needed, after accurate evaluation, addressing the following aspects, in a future release of this area of work of the ENI System specified in ETSI GS ENI 005 [i.3]:

- What is the data format when data is used to interact between specific FBs? This could mean that $I_{norm-sem}$ could be structured data because normalized data is usually structured and structured data is more easy to use, I_{sem-km} could be graph data because some knowledge is represented by using graphs.
- How is the data converted in order that it could be understood and used by other FBs or external systems? This could mean that the data from the Knowledge Management FB could be an AI model which is acquired by training based on the data from other FBs, the data from the Policy Management FB could be converted to appropriate commands or instructions that are adapted to external systems.
- How is data acquired and processed in a more efficient way in ENI closed control loops?

In order to enable network data to better support intelligent network data processing, some new technological trends are emerging. It is recommended that some of them are adopted in the future, e.g.:

- **Flexible data acquisition:** Data is able to be collected at a dynamic sampling frequency (e.g. data is collected with a higher or lower frequency) or dynamic granularity (e.g. more or less fine-grained) than the last collection. These are two sampling dimensions. The sampling is handled by the control loops, that decide the granularity and frequency of data collection. This is why data acquisition is required to become flexible.
- **Automatic data processing:** One or more closed control loops could decide to change the type of data to be collected based on system goals. The decision could be taken upon the reception of inputs based on data evaluation and optimization. As none of these tasks are done in a closed loop as they are too costly, and would prevent the loop from running in real-time, they are performed in the Data Ingestion Functional Block and the Normalization Functional Block This will be addressed in a future release.
- **Intelligent data management:** Different types of data require different types of processing. If rule based mechanisms are used, this implies a high level of complexity. However, mechanisms based on learning data characteristics and similar relationships between data are promising and it is recommended to be explored in a future release. These mechanisms enable automatic data label assignment. Label assignment will be addressed in a future release.
- **(Logical) Distributed data storage:** The decoupling of storage and computing resources is important to enable different types of horizontal and vertical storage scaling.

Annex A:
Change History

Date	Version	Information about changes
2019-09	0.0.1	Initial early draft with skeleton
2019-12	0.0.2	Combine ENI(19)012_029, ENI(19)012_030r1, ENI(19)012_031r2, ENI(19)012_032r1, ENI(19)012_033r1 and ENI(19)012_039r2
2020-03	0.0.3	Combine ENI(20)000052r2 and ENI(20)000053r1
2020-03	0.0.4	Combine ENI(20)013_027r1, ENI(20)013_028r1 and ENI(20)013_030r1
2020-06	0.0.5	Combine ENI(20)000_067
2020-06	0.0.6	Combine ENI(20)014_016, ENI(20)014_017r1, ENI(20)014_018, ENI(20)014_026r1, ENI(20)014_028r1, ENI(20)014_029r1, ENI(20)014_031r1 and ENI(20)014_042r1
2020-08	0.0.7	Combine ENI(20)000_123
2020-09	0.0.8	Combine ENI(20)015_037
2020-10	0.0.9	Combine ENI(20)000_144 and ENI(20)000_145
2020-11	0.0.10	Combine ENI(20)000_181r1 and ENI(20)000_182

History

Document history		
V1.1.1	June 2021	Publication