ETSI GR ZSM 011 V1.1.1 (2023-02)

Zero-touch network and Service Management (ZSM); Intent-driven autonomous networks; Generic aspects

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Reference

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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) Zero-touch network and Service Management (ZSM).

Modal verbs terminology

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1 Scope

Intent-based management enables simpler, more user-friendly expressions of input information, and higher flexibility in automation. Intent is a key enabler to increase automation and make management simpler; therefore the present document investigates the potential use of intents as key enabler for enhancing autonomous network and service management within ZSM framework. It provides a formal definition of intents and a list of principles of intent-driven management, leveraging existing standardization work. Some use cases are also included in the present document to provide examples of management domains where intents are applicable and capabilities that may be needed. Intent-driven management within the ZSM framework is investigated and the concept of an intent management entity is introduced, which is responsible for the life cycle management of intents and the exchange of intents between different management domains. The present document also maps the intent management entity with the concept of closed loops that is specified in ETSI GS ZSM 009-1 [i.11]. Intent modelling is also investigated, and two different approaches are proposed. The present document defines intent life cycle phases and a state diagram, together with a set of (mandatory and optional) interface capabilities that are needed for the life cycle management of intents. Finally, additional aspects such as conflicts between intents, intent translation, and intent testing are investigated. The present document outlines potential future work based on the topics explored and the critical areas that were identified in 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 ZSM 005: "Zero-touch network and Service Management (ZSM); Means of Automation".

[i.2] TM Forum IG1230: "Autonomous Networks Technical Architecture v1.1.0".

[i.3] IETF RFC 9315: "Intent-Based Networking - Concepts and Definitions".

[i.4] ETSI TS 128 312: "LTE; 5G; Management and orchestration; Intent driven management services for mobile networks (3GPP TS 28.312 Release 17)".

[i.5] TM Forum IG1253: "Intent in Autonomous Networks v1.2.0".

[i.6] TM Forum IG1253A: "Intent Common Model v1.1.0".

[i.7] TM Forum IG1253B: "Intent Extension Models v1.1.0".

[i.8] TM Forum IG1253C: "Intent Life Cycle Management and Interface v1.1.0".

[i.9] TeraFlow Project: "Secured autonomic traffic management for a Tera of SDN Flows".

NOTE: Available at https://www.teraflow-h2020.eu/.

[i.10] TeraFlow Project - Scenarios.

NOTE: Available at https://www.teraflow-h2020.eu/node/161.

[i.11] ETSI GS ZSM 009-1: "Zero-touch network and Service Management (ZSM); Closed-Loop Automation; Part 1: Enablers".

[i.12] W3C® Recommendation 25 February 2014: "RDF 1.1 Concepts and Abstract Syntax".

NOTE: Available at https://www.w3.org/TR/2014/REC-rdf11-concepts-20140225/.

[i.13] ETSI GS ZSM 007: "Zero-touch network and Service Management (ZSM); Terminology for concepts in ZSM".

[i.14] Dave Lenrow: "Intent: Don't Tell Me What to Do! (Tell Me What You Want)".

NOTE: Available at https://www.sdxcentral.com/articles/contributed/network-intent-summit-perspective-david-lenrow/2015/02/.

[i.15] ETSI GS ZSM 009-2: "Zero-touch network and Service Management (ZSM); Closed-Loop Automation; Part 2: Solutions for automation of E2E service and network management use cases".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI GS ZSM 007 [i.13] and the following apply:

autonomous entity: part of a network that is capable of making and actuating decisions within its specified degree of autonomy and area of influence

NOTE: In the ZSM Framework a Management Domain is an example of an autonomous entity.

intent: formal specification of the expectations, including requirements, goals, and constraints, given to a technical system (see TM Forum IG1230 [i.2])

intent handler: logical entity that receives intents (i.e. the intent information objects) and handles them in the domain that is responsible for that intent's fulfilment

NOTE: An intent handler is not allowed to modify and/or remove an intent but can reject to fulfil it. It fulfils the requirements and goals, based on the resources and solutions it has available once it has accepted the intent. An intent handler reports back to the intent owner regarding the intent fulfilment.

intent information object: information object that represents a specific set of requirements, goals and constraints which are structured according to the intent IOC

intent information object class: object class that describes the type, structure and relationships of the information elements that specify the requirements, goals, and constraints of an intent

intent management entity: autonomous entity in a domain that can play the role of intent owner and/or intent handler and is capable of making and actuating decisions to fulfil intents

intent negotiation: procedure involving an intent owner and an intent handler where the intent fulfilment terms are settled prior to the intent being accepted by the intent handler

NOTE 1: Alternatively, an intent negotiation could also result in a rejection of the intent.

NOTE 2: An intent handler is an autonomous entity in a domain for the aspect of intent fulfilment.

intent object instance: unique managed object instance that is instantiated at the intent handler (MnS producer) based on the information of intent requirements, goals and constraints sent to the intent handler (MnS producer) by the intent owner (MnS consumer)

intent owner: logical entity that originates intents (creating intent information objects) and is responsible for managing its lifecycle. Ideally only an intent owner is allowed to manage the intent lifecycle

opportunity cost: cost of a particular good or service compared to an alternative

NOTE: Opportunity cost is a term used in economics. When consumers or businesses make the decision to purchase or produce particular goods, they are doing so at the expense of buying or producing something else. This is referred to as the opportunity cost.

producer utility: total benefit for a producer to supply a good or service

utility: total satisfaction received from consuming a good or service

NOTE: Utility is a term used in economics. Economic theories based on rational choice usually assume that consumers will strive to maximize their utility. The utility is subjective. It depends upon the mental assessment of the consumer and is determined by several factors which influence the consumer's judgment.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI GS ZSM 007 [i.13] and the following apply:

CFS	Customer Facing Service
IOC	Information Object Class
MnS	Management Service
OPEX	OPerational EXpenditure

4 The concept of intent-driven management

4.1 Introduction

In an autonomous networks management framework that is purely intent-driven, all goals and expected behaviour are defined with intents. The management framework will only perform operations that relate to the fulfilment and assurance of an intent, which means that all goals - including those that may have been considered "common sense" in human-operated systems - are to be expressed as intents.

An intent in an autonomous management framework is expressed declaratively - that is, as a goal that describes the properties of a satisfactory outcome rather than prescribing a specific solution. This gives the framework the flexibility to explore various solution options and find the optimal one. It also allows the framework to optimize by choosing its own actions and decisions, e.g. exactly which service to instantiate, or configuration to make, that will ultimately maximize utility.

Unlike traditional software systems, where requirements are analysed offline to detect and resolve conflicts prior to implementation, intents are added to an autonomous framework during runtime. Adaptation to changed intent as well as conflict detection and resolution are therefore essential capabilities of an autonomous framework.

Expectations originate from contracts or business strategy and remain constant when the underlying framework is replaced or modified. Consequently, when setting up the intents, it is important that they are formulated in an infrastructure-agnostic form, so that they can be transferred across network and infrastructure implementations, i.e. vendor, technology, and operator agnostic.

As described in clause 5.2, intents can be used for interactions between management service consumer and management service producer in intent-driven management. From the management service consumer's perspective, an intent that is used in such an interaction is agnostic to the management service producer's infrastructure and the resources that are ultimately used in the intent fulfilment.

In short, the intent establishes a universal mechanism for defining expectations for different layers of network operations. It expresses goals, utility, requirements, and constraints. It defines expectations on service delivery as well as the behaviour of the autonomous management framework and the underlying managed network.

An original intent will be transformed and decomposed when transferred between different domains. At each stage it can be decomposed into several new declarative intents and also, partly or completely, transformed into various actions.

In addition, the decomposition and transformation will happen not only when the intent will be transferred between different domains but also between the different levels and layers of operational management to define for example needs, requirements, constraints, and targets.

Although purely intent-driven management frameworks are foreseen, it is more likely that intent-driven management will complement the traditional imperative (not intent-driven) management solutions.

4.2 Definition of intents

4.2.1 Introduction

ETSI GR ZSM 005 [i.1] introduced intent-based approach as a means of automation. Clause 4.3.0 of ETSI GR ZSM 005 [i.1] summarizes how the notion of intents emerged in the telecommunications industry and how some of the main academic and industry work have adopted this concept in the area of network and service management and automation. Also, the later TM Forum's IG 1230 [i.2] presents the concept of intent and the evolution of the concept over time in clause 5.7, showing mainly how intent is defined and used in different standardization organizations.

The notion of intent as a concept and its role in the telecommunication industry has evolved over time from being policy-centric towards being a means for declaration and communication of goals, requirements, and constraints to parts of a technical system, such as a management system. The setting of intent is often linked to humans' expectations and desires, but it can also be used to express goals to be exchanged between machines or within an autonomous system.

IRTF NMRG [i.3] has defined intent as "*A set of operational goals (that a network should meet) and outcomes (that a network is supposed to deliver) defined in a declarative manner without specifying how to achieve or implement them*".

In ETSI TS 128 312 [i.4], intent is defined as "a desire to reach a certain state for a specific service or network management workflow". Besides that, "*an intent specifies the expectations including requirements, goals and constraints given to a 3GPP system, without specifying how to achieve them*".

The same general definition has been adopted in TM Forum's IG 1230 [i.2] as a baseline. TM Forum's work emphasize that from the user's perspective, an intent expresses the expectation the user has with respect to the behaviour of the system. Intents should be used to convey the goals needed to ultimately fulfil humans' expectations. In this sense, according to TM Forum's IG 1230 [i.2], an intent can also be defined as "*the formal specification of all expectations including requirements, goals, and constraints given to a technical system*".

Based on the definitions presented above, there is a common understanding in the industry that an intent is a knowledge object that is used to describe the expectations to a system in a way that allows autonomous operations to be performed by the system receiving such intents. The ZSM framework should use the same definition when applying an intent-driven approach in the zero-touch networks and services management.

Therefore, the adoption of intent definition as in TM Forum IG1230 [i.2] is proposed:

> *"Intent is the formal specification of the expectations, including requirements, goals, and constraints, given to a technical system".*

4.2.2 Principles of Intent

Properties and Implications of Intent are well defined in [i.2] and some others of the previously mentioned documents.

As conclusion the following principles of intent are identified for ZSM:

1. Intent establishes machine-processable knowledge

Intents are formal specification created for a technical system, which means that they establish machine-readable knowledge to be considered by the autonomous management. In an autonomous network, where business goals and requirements can change dynamically and the operations need to quickly adapt without human intervention, the business objectives of the operators as well as the expectations of the customers and users need to be conveyed in some means of knowledge, and this is the main purpose of intents.

2. Intent is declarative, so it leaves any implementation detail internal to the solution provider

Intents define goals, requirements, and constraints, which should be provided in a declarative form. The definition excludes all imperative implementations and solutions aspects. Therefore, intents leave out the implementation of the details of how the network and service is operated to the internal management capabilities of the autonomous network. In this respect, artifacts such as workflows, policies, decision rules, etc. are still needed to realize intent-driven autonomous networks. Such tools will be used internally to the autonomous systems according to network operator's strategies.

3. Intent is focused on expectations of the results for the consumer

Intents focus on a specification of expectations, reflecting the idea that intents are expressed from a consumer's perspective. Intents can originate directly from humans, e.g. customers or operators using intents to communicate to an autonomous system their expectations. It is the job of the autonomous system to fulfil those expectations, while the intent originator may play a supervisory role. Intents can also be generated internally within the autonomous system and can be used between the autonomous entities to influence the details of the specific wanted behaviour and contribute to the overall fulfilment of human expectations (expressed by intents initially created).

4. Intent is formally expressed so it is machine-processable and readable for human

Finally, one of the most important aspects of intents is that they are formally expressed so that they can be interpreted by machines as well as by humans. The sender and receiver of intents need to agree in their interpretation; therefore, there should be no ambiguity in their meaning. The formal expression and unambiguous meaning of intents can be achieved by well-defined information models that completely define the semantics and vocabulary that is required for the operation of each autonomous system that uses intents. The intent models that can be defined in the ETSI ZSM scope are presented in clause 5.4.

5. Intent supports complete automation of intent owner-intent handler interactions as well as of intent-defined service delivery

Intents are abstract, which allows them to be formulated by intent owners without requiring intent owners to learn details of the intent handler's managed entities. This, combined with e.g. suitable intent owner-intent handler interface operations and closed loop-based instantiation and maintenance of services by intent handlers, supports complete automation of intent owner-intent handler interactions and of operations through to service delivery and maintenance.

4.2.3 Ensuring trust in intent-driven autonomy

As expressed with principle 2 above, all implementation details and insight to the intent processing are left to the particular solution of an autonomous intent handling.

To address the expectations of a guaranteed service quality and most secured processes service providers require a high level of control, which raises expectation to get more insight into the intent handling process itself. Therefore, additional capabilities can be optionally enabled.

1. Intent handlers offer optional insight to the intent handling process

Intent handlers may expose the sequence of generated actions or operations, when requested by an authorized user.

2. Intent handlers offer optional explicit intent verification

An Intent can e.g. be explicitly tested at any time if intent expectations are still met, when requested by an authorized user.

4.2.4 Additional aspects of Intent

The introduction in clause 4.1 describes intent as a key enabler in a management framework for autonomous networks. When coming to the more concrete definition how an intent can be expressed (i.e. in an intent information object), also looking at the process of intent-handling within a ZSM framework, different business goals may be considered.

Table 4.2.4-1

#	Goal	Means	Description
a)	Autonomy	Service Abstraction	Avoiding service knowledge for the consumer, express the need, not the concrete service, let the producer decide autonomously about concrete service and how to build it
b)	Human Language	Language Translator	Allows to formulate an intent with human language, to be translated into machine readable intent information object
c)	Flexible Offerings	Parameters to Negotiate	Allows to negotiate for example quality of a service
d)	Provide Best Producer	Intent Request Broker	Find the best service producer/intent handler for the purpose
e)	Time to market	May vary	Enable runbook generation at runtime, avoid coding of runbook workflows

Service abstraction to enable autonomy as in a) is the most relevant aspect of intent and the focus of the present document. An intent handler can decide autonomously on the concrete service instantiated, how this is assembled and how its quality is assured. In the simplest case, the structure of an intent information object, may be similar to a CFS (Customer Facing Service) specification, catalog based, just at an abstracted level. The handler decides on the concrete service and resource composition and its quality assurance.

The full value of an intent comes with goals b), c) or d) it may support human natural language, negotiation e.g. about the quality of service, or find the best service producer for an intent. All these goals are supportable, given the intent information object has the right structure to express the expectation of the intent consumer to the intent producer.

However, looking at the growing complexity of networks, the fast-growing number of possible service offerings, the effort to implement the processing of new intent offerings has to be seen as well as shown with goal e). Therefore, simplification to implement intent processing is another goal, to lower cost of automation and reach faster time to market. The structure of an intent information enables simplification for the consumer, but not necessarily for the producer. Hence the present document touches also implications to the intent management entity implementation.

4.3 Examples of use cases considered

4.3.1 Introduction

This clause introduces use cases where intents play an important role in the autonomous service and resource management. The list of use cases is non-exhaustive and is meant to illustrate the use of intents in different scenarios and to provide examples of management domains where intents are applicable and capabilities that may be necessary for the realization of intent-driven management.

4.3.2 Automotive use case

4.3.2.1 Description

In the automotive use case, mobile operators not only provide the connectivity to the connected cars, but also deploy MEC and cloud infrastructure along the Transport Network (TN) to host the CCAM (Cooperative, Connected, and Automated Mobility) applications. The huge scale and diversity of CCAM services impose 3 main requirements for TN services: low-latency, high-capacity, and massive flow management. For example, in Beyond-5G (B5G) networks, the objective is to collect telematics and driver behaviour data and analyse it to ensure the vehicle's performance, efficiency, and safety. It is estimated that each car will produce and send 25GB of data to the cloud every hour. MEC is deployed to distribute the functionalities between the edge and the core clouds to reduce the number of flows and the capacity required, thereby lowering the E2E latency.

TeraFlow project [i.8] (funded by the European Commission under the Horizon 2020 Programme) is working on smart connectivity beyond 5G. It aims to build a new type of secure cloud-native SDN controller by integrating current NFV and MEC frameworks and have new features for flow management at the service layer.

The TeraFlow OS is designed to unify the management of computing, storage, and networking resources; deploy integrated services (e.g. provision of cloud & edge computing resources and connectivity between them); and optimize the cloud and network resources in an integrated way.

The E2E CCAM services span multiple TN domains, each of which is deployed with a per-domain TeraFlow OS instance. In each TN domain, the physical infrastructure is virtualized to create multiple co-existing virtual TNs (VTNs) with specific QoS.

These TeraFlow OS instances cooperatively manage the E2E services composed of multiple E2E VTNs.

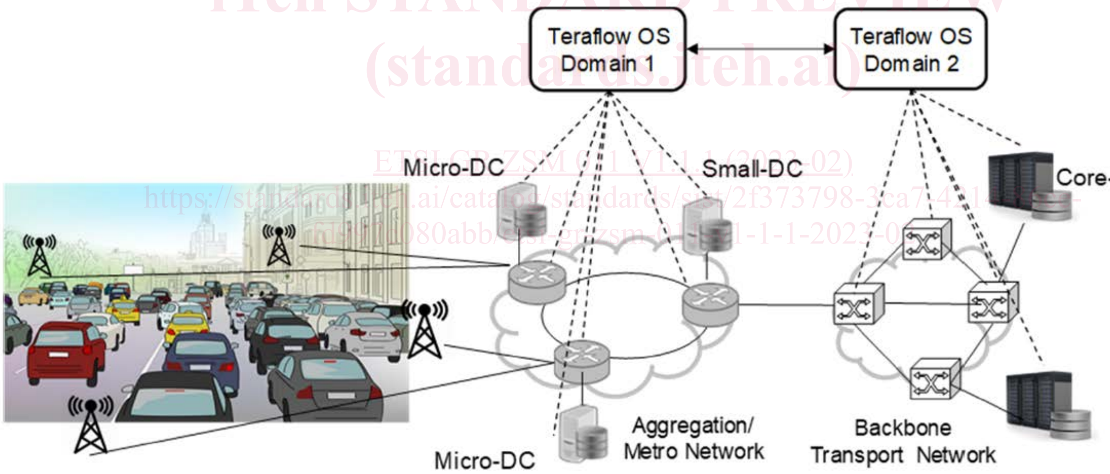

Figure 4.3.2.1-1: TeraFlow Automotive use case scenario (source: [i.9])

4.3.2.2 KPIs

The main KPIs for the CCAM services in E2E are:

- Resource efficiency.
- Multi-tenancy support.
- Latency.
- Positioning.
- Trust/privacy.
- OPEX reduction.

These KPIs cover both technology and business aspects. They are applied to both TNs and cloud infrastructure, which are administrated by different service management systems. To assure the specified KPIs, coordination is required:

- Internally: between TeraFlow OS instances to offer TN slicing services.
- Externally: with 5G network slicing management entities (e.g. ETSI ZSM, 3GPP, ETSI NFV MANO, ETSI MEC) to offer 5G slicing services.

The assurance of these KPIs require different actions. For example, QoS-based KPIs are related to network configurations. Business KPIs (e.g. OPEX reduction) are specified by vertical customers and need to be translated into the network service KPIs. KPIs on security and privacy need to be assured by deploying proper technologies, e.g. security, isolation, etc.

4.3.2.3 Intents

The above KPIs are requirements that can be represented as part of the intents provided by automotive verticals. Such intents will be sent to the customer-facing service portal (e.g. TeraFlow OS or other CSP portals), which are the ZSM framework consumers.

One important step is to interpret these intents into domain-specific intents:

- RAN domain intents.
- CN domain intents.
- MEC domain intents (if MEC is deployed).
- TN domain intents. Note that TN domain intents are defined for TN slices, which then need to be further decomposed into:
    - Access segment intents.
    - Aggregation segment intents.
    - Metro segment intents.
    - Core segments.

The domain-level intents should be technology-agnostic, e.g. TeraFlow OS will support a technology-agnostic NOS LCM, e.g. with deployment, upgrade, and migration. Then, the domain-level intents will be translated into technology-specific intents and realized by individual domains.

Two key capabilities are needed for intent-based management in this UC:

1) Intent decomposition and interpretation/translation across layers:
    a) Intent decomposition: from customer-facing intents (business-oriented and E2E-based) to network-facing intents (technology-oriented, network-domain-based, and technology-agnostic) → decompose the E2E business intents into network-domain intents.
    b) Intent translation: from network facing intents (technology-agnostic) to resource-facing intents (technology-specific).
2) Intent assurance:
    a) Certain monitoring mechanisms are demanded to monitor "intents" at all layers (customer-, network-, and resource-facing).
    b) Measurement and monitoring of intents should be supported.

NOTE: This use case deals primarily with resource management, but the KPIs, the management domains and the key capabilities listed above are also applicable for the management and optimization of managed services.

4.3.3 Cloud private line services

4.3.3.1 Description

Cloud Private Line (CPL) services connect cloud service users to edge or cloud data centres, and edge or cloud data centres to each other, with deterministic connection performance. They may represent point-to-point, point-to-multipoint, multipoint-to-point, or multipoint-to-multipoint connectivity service topologies, and may be connected or connection-oriented in nature. Data flow mapping to CPL services is port-, packet- or frame-oriented and CPL services may or may not include inspection and differential mapping of packets or frames to connection services at connection service ingress ports. Service and/or supporting technology types include Ethernet, MPLS (Multi-Protocol Label Switching), OTN (Optical Transport Network) and DWDM (Dense Wavelength Division Multiplexing), solely or in combination. Collections of CPL services may be considered as Transport "Slices" and defined and provisioned collectively; here CPL services are assumed to be defined and provisioned individually.

Figure 4.3.3.1-1 illustrates an example of a CPL service infrastructure that uses EOO (Ethernet-over-OTN) technology. User data (e.g. IP packets or Ethernet frames) are carried by Carrier Ethernet Services, which operate over Ethernet Virtual Connections (EVCs). The EVCs provide service OAM (Operations, Administration and Maintenance), while service isolation and traffic protection are offered by the underlay OTN services. Right-sizing and topological configuration of service tunnels, or groups of tunnels, is provided by reconfigurable ODUFlex and DWDM technologies.

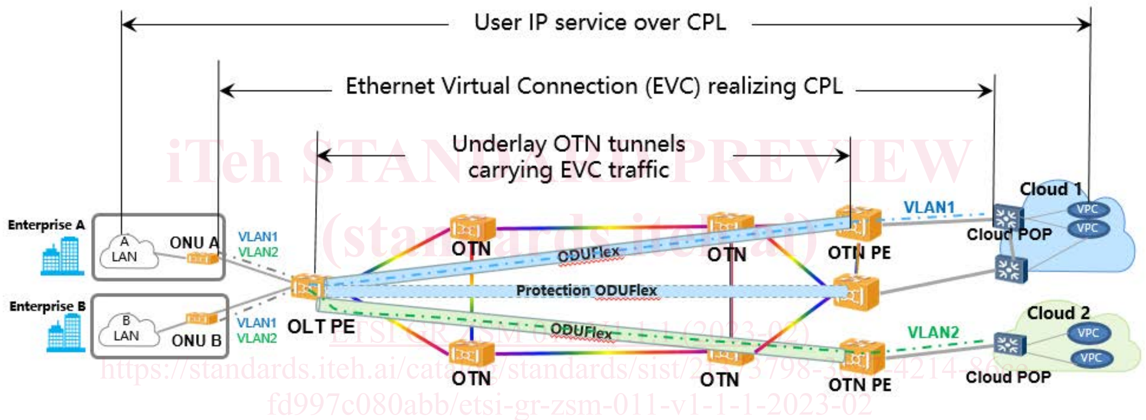

Figure 4.3.3.1-1: Illustration of a CPL service infrastructure based on EOO (Ethernet-over-OTN) technology

Data centres may be operated by the CPL service customer, by the CPL services provider, by some other service provider(s), or by any combination of these. CPL service traffic consists in machine-to-machine data flows with a range of characteristics. Some data flows are essentially continuous, may require low or medium bandwidths, and may be anywhere from relatively latency-insensitive to highly latency-sensitive (e.g. synchronous data mirroring). Other data flows may comprise block data transfers, of varying sizes and completion time requirements, may occur on varying schedules, and may require small to very large bandwidths; they may also have varying latency sensitivities. The application drivers of individual data flows may depend on a range of application circumstances that may vary in time. Even CPL service availability and restoration requirements are variable and derive from application requirements associated with particular data flows.

There is demand, in multiple market segments, for dynamically user-driven mass-customized CPL services, having deterministic connection performance, when in operation, to serve these requirements. Such a paradigm would replace both static port-to-port "large pipe" private line services and statically-configured services that rely on statistically-based sharing of transport resources among data flows that require - perhaps significant - overprovisioning of resources to prevent service performance degradation under unfavourable aggregate data flow conditions. This new paradigm is useful to both service consumers and service providers, as: services may be closely matched to specific needs; service performance is deterministic in operation, providing e.g. determinism in block data transfer times; service delivery is network resource-efficient, as resources may be allocated to closely match the minimum detailed needs of every service; and services may be better-monetized, as no service parameter needs to be "given away free". Obviously, however, a dynamically mass-customized service paradigm, operated at any reasonable scale, requires a high degree of automation of service delivery and maintenance processes.

Dynamically mass-customized CPL services are driven operationally by CPL service consumers, either semi-manually (e.g. through a user-facing provisioning portal) or - more usefully - directly by consumer scheduling software systems. Intent is obviously a useful API and service-driving paradigm to support such capability.

4.3.3.2 Intent parameters

Parameters relevant to CPL service intents include:

- Service end-points.
- Service connection topology type.
- Service ingress flow identifiers, if applicable.
- Bandwidth (e.g. minimum, range, etc.).
- Latency (e.g. maximum, range, etc.).
- Scheduling parameters (e.g. start/stop/resume schedules, overall or specified per-parameter).
- Availability (e.g. minimum time-based availability percentage).
- Restoration (e.g. maximum time-to-restore on failure).

Typically, CPL services will be delivered by one or more Transport Management Domains (MDs). In a fully ETSI ZSM-compliant framework, the CPL service Intent API would lie between a service consumer system, or some intermediating aggregator, and the provider E2E MD. Interactions between the E2E MD and the Transport MD(s) could be of any type: intent-driven, service-based or resource-based. See Figure 4.3.3.2-1.

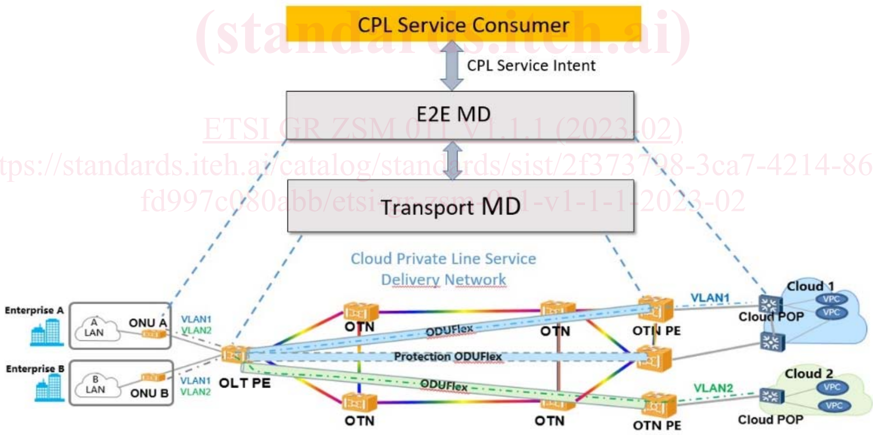

Figure 4.3.3.2-1: Illustration of a CPL service infrastructure based on EOO (Ethernet-over-OTN) technology, showing ETSI ZSM domains and APIs

Economic considerations - e.g. service pricing - could in principle be a component of an intent expression, in terms of limits expressed by the intent owner, possibilities returned in "negotiation" by an intent handler, etc.

Some existing service-based API models reflect similar parameters to those listed above, and thus may be usable - directly or with appropriate extensions - as the basis for CPL service Intent APIs. The operational difference between service-based and intent-driven systems lies in the strict separation of information regimes between owner and handler domains (per clause 4.3.3.3) and in service delivery handling, through closed loops, by Intent Management Entities (IMEs - per clauses 5.1 and 5.2).