TM Forum Introductory Guide

Study of Telecom Industry Intent Meta-Modeling Approaches

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Executive Summary

Several standards developing organizations (SDO) are actively working on the topic of Autonomous Networks and the associated concept of intent-driven management. One of the key building blocks of intent-driven management is the *intent meta-model* which helps by providing an abstract representation of the schema and rules of the intent model, irrespective of the management domain or specific management layer, and enables the extension of such a model wherever necessary, depending on the context of usage. This is critical because the meta-model of the intent is one of the architectural considerations that can influence the functional blocks required for the overall autonomous network system to derive the semantic meaning and context of the intent as well as helps to map intent to internal actions without ambiguities or conflicts.

This study explores the approaches followed by different standardization organizations for intent meta modeling and highlights the readiness, relevance of use as a reference methodology, and the context of usage that identifies what aspect of the SDO artifact can be leveraged. It should be noted that this study does not compare the SDO approaches directly, because the objective, context, and the maturity of intent-driven management specification development in the various SDOs considered are different. Hence, it is advised that this document is referred to as informative content and for identifying the best practices. This study helps CSPs to match the SDO intent modeling capability with the business requirement, applicability across wider use cases or spanning multiple domains. Additionally, depending on the transformational stage of the CSP towards Autonomous Networks, an appropriate set of capabilities can be planned and incorporated based on the overall scope and development roadmap documented by the SDOs.

The following table summarizes the intent meta-modeling approaches of different standard organizations and key characteristics.

	Characteristics			
SDO Approach	Meta-model approach	Intent expression language (DSL or Schema specification format)	Context of use (What aspect of the SDO artifact can be used for intent meta modeling?)	Relevance (Relative maturity to use as a standard intent meta-modeling approach)
Semantic Web Techniques	RDF/RDFS/OWL based Ontology	SKOS, RDF, RDFS, OWL or Turtle	Simple : Taxonomy/Thesauri based Advanced : Ontology/Knowledge graph based	High , but can consider evolutionary and intermediate steps
MEF DSL	Restricted DSL for specific domain/Use Case (SD-WAN)	Restricted natural language, Restricted DSL	Start simple with a specific domain DSL and specialized DSL processors	Medium , DSL limited to a specific use case

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	Characteristics			
ETSI ZSM	Dynamic Service Descriptor (DSD) with object behavior modeled as policy	Not available , but directions indicate a DSL	Views on DSD is worth referring to	Low , no reference model that can be readily used for implementations
ETSI GANA	Ontology based high-level business language that can be translated to domain specific Service and Network Profile	Reference PoCs for specific domains available with recommendation on deriving Service and Network profiles	Wireless Access and BBF Architecture specific Use case/PoC that mention how profiles are derived from GANA knowledge plane	Medium , currently limited use cases which are domain specific. Knowledge Plane level information gathered in specific use cases/PoCs worth referring to.
ETSI ENI	Intent policy expressed as external DSL	Not available , but directions indicate a restricted DSL	Based on Unified Policy Information model Based on external DSL	Medium, Require extra effort to come up with an external DSL
3GPP	Intent expression as a composition of intent object and intent action	Not Available (A simple logical representation of Intent expression available)	Extending the Intent Expression consisting of Intent Object and Intent Actions along with respective properties	Medium , basic reference model , require additional effort for domain/ UC specific DSL
IETF Intent Classification	None specified , but Intent classification methodology helps to build a conceptual model	Not in scope	Intent classification methodology to build a conceptual model of scope and entities	High , Build conceptual view
IETF NEMO	Restricted network DSL	NEMO yang model	Extend the network intent model to express network specific intents	Medium, for a specific domain with restricted language
ONAP	Intent expression as a composition of intent object	Refers to 3GPP Intent Expression	Experimental use of Intent framework reference implementation with PoC DSL representation , translation, decision-	Medium, Require use case specific instrumentation and schema definition

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	Characteristics			
	and intent action		making and execution mechanisms	
O-RAN	RAN Intent representing a high level business goal	Not in scope	Not ready for use as O-RAN does not have a well-defined scope for RAN intent	Low , no reference model or approach

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1. Intent Meta-Modeling Approaches

TMF Specification IG 1244A (link: TBD) gives a formal representation of the intent meta-model and its relationship with the domain-specific information model. There are many techniques used across the industry verticals and SDOs for expressing intent meta-model (or knowledge organization schemes) in a machine-readable format. In this section some of these approaches are examined and also the context under which such approaches are applied is analyzed.

1.1. Semantic Web Standards (RDF, RDFS, SKOS, OWL) from W3C

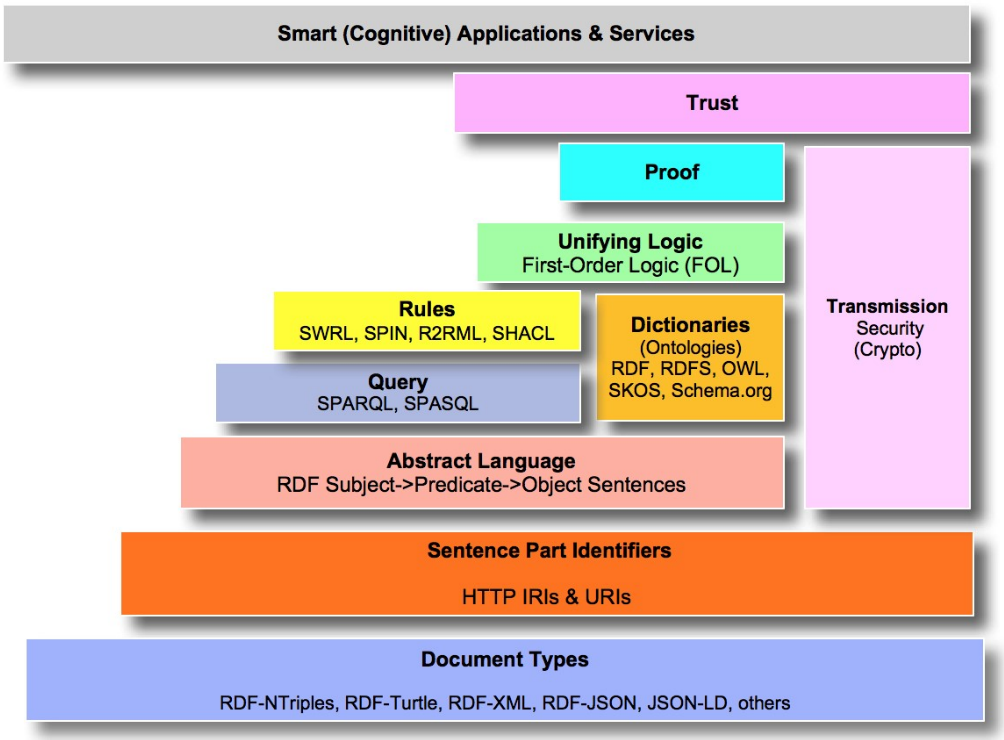

Figure 1. Semantic Web Stack (Source: [Idehen, Kingsley Uyi. 2017. "Semantic Web Layer Cake Tweak, Explained." OpenLink Software, via Medium, July 14])

These standards are a set of instruments developed by W3C for modeling semantic knowledge or linked data that enable large-scale integration of, reasoning on, the data on the web that helps to realize semantic web vision of "Web of linked data". Some important modeling specifications in the semantic web stack that may be relevant for intent modeling are described below.

Resource Description Framework (RDF): A standard format for exchange/interoperability of data. RDF is available in various serialization formats such as RDF/XML (XML based syntax), Turtle, JSON-LD, RDF/JSON, etc. In simple words, RDF is used to represent simple relationships between concepts (subject, object, predicate).

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Simple Knowledge Organization Scheme (SKOS): is a data model representation to express controlled vocabulary (such as thesauri, classification schemes, and taxonomies) that can be exchanged between computer applications and published in a machine-readable format on the web. SKOS is primarily used for indexing, information retrieval or for navigation purposes. SKOS represents Concepts (not Classes that can be instantiated unlike in RDFS and OWL) identified with URI and grouped into a Concept Scheme. SKOS is represented using the web standard such as XML and RDF (Resource Description Format).

Resource Descriptor Framework Schema (RDFS): A general-purpose language used for describing the properties and classes of the RDF resources (subject, object, predicate). RDFS serves as a base for ontologies. RDFS gives RDF more expressive vocabulary through classes, subclasses, and properties.

Web Ontology Language (OWL): OWL semantic web language used to build ontologies or schema on the top of RDF datasets, describes relationships between classes and uses logic to make deductions, express constraints in relations. It can also construct new classes based on existing information. OWL is available in three levels of complexity -- Lite, Description Language (DL), and Full. OWL is based on RDF and RDFS. SKOS is an Ontology created in OWL for representing controlled vocabulary, thesauri, and taxonomies.

To summarize, the above standard formats help to represent knowledge in a machine-readable format with different levels of complexity and richness of semantic information it can capture. For example, a domain level concept can be represented in a basic format like SKOS with RDF vocabulary (for subject, predicate, object representation), a set of concepts (Concept schemes,) that share characteristics and relationships can be represented using RDFS or OWL based classes, properties or individuals depending on the richness of vocabulary intended to represent the knowledge (RDFS vs OWL).

1.1.1. Context of use and relevance for Intent Meta-Modeling

As stated above semantic web modeling languages are primarily used for interlinking data on the web across domains and derive semantic information (based on the metadata and the relationships) that can be used for various use cases such as web search, digital library, financial services, life sciences, etc.

Leveraging the Semantic web modeling techniques defined above, intent can be modeled as simply as a hierarchical taxonomy to a more complex ontology-based knowledge graph depending on the expressive power and the reasoning complexity that can be accommodated. The following are some approaches that may be relevant for the intent meta-model.

- Taxonomy/Thesauri based approach (Knowledge organization approach): Terms or concepts (vocabulary of terms) organized into hierarchical or associative manner. Less complex intent vocabulary can be represented in a SKOS format. Taxonomy/Thesauri is typically used to represent concept labels or search (the relationship between concepts for display or for web search) that can be used for lookup or translation of intent through entity categorization, key phrase extraction, etc. This may act as a base for building the ontology model.
- Ontology and Knowledge graph-based approach (Knowledge representation approach): Ontology is used primarily for knowledge modeling focused on complex semantics of concepts and the relations among concepts, their properties, attributes, values, constraints, and rules. Since intent is a semantic representation of goals that express requirements and constraints, ontology based Meta-modeling can be one of the choices, which means ontology can be used as a base contract for defining intent, its

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scope, and boundaries. Ontology based meta-modeling also enables the extension of the intent schema and reuse/reference entities from existing domain-specific information models to create a more expressive and formal intent language.

A knowledge graph is a collection of interlinked entities, and the ontologies form the base schema of the graph. Refer to the discussion here on difference or relationship between the knowledge graph and ontologies. Additionally, the Enterprise Knowledge white paper explains the relation between Ontology and Knowledge graph with an example For an intent-driven system, an intent model with populated values (instances of ontology concepts or facts) can be represented as an element (semantic knowledge) of the knowledge graph. Knowledge graphs can be an enabler for an intent-driven system especially when a) AI-based algorithms are trained with the graph to derive contextualized knowledge or facts that can be used for further downstream action b) a time series indexed inventory of intents can be maintained for audit or system recovery. However, the temporality of the knowledge graphs needs to be noted, which may influence the static or transient nature and associated implementation requirements to support such characteristics.

1.2. MEF Restricted Intent DSL

MEF Intent-based orchestration project (W71) focuses on "*developing common, multi-vendor, interoperable, intent-based policies to support use cases, services, and standards*". There are two work items highlighted as part of the W71 specification work – *a) Intent-based policies that are defined as statements that express the goals of the policy in an implementation/vendor/device-independent manner b) system architecture that supports closed-loop, black-box "intent-engine"*

At the time of this writing MEF, W71 is still under active development, however, the contributions related to MEF intent DSL is worth referring here for the context of this paper. The MEF DSL contribution (link, not a formal specification) focuses on a restricted intent DSL for SD-WAN service catering to the Business User. A revised scope of the MEF 71 work item also indicate the development of intent policy for SD-WAN through a separate project W85 which includes Business user DSL, Application user DSL and compiler for both.

The intent DSL is expected to have the following characteristics:

- captures the concepts for a particular domain or interface (for example SD-WAN, MEF LSO Cantata) , for a particular type of user (e.g., Business user, Application Developer user, etc.)
- Specify concepts/goals through grammar or use of programming language to program solutions.
- A Lexicon/Dictionary is used to disambiguate the intent input or derive semantic meaning from the intent input.

The MEF contribution referred here gives an exemplary DSL idea for a "Skype for Business" service intent.

For the MEF 71 intent engine scope there are initial thoughts shared through contributions that indicate the presence of intent compiler that leverages Lexicon to disambiguate the input and a parsing logic that recognizes named entities as well as derives semantic context. The intent parsing logic recognizes named entities in the intent and maps it to different classes of interest such as People, Locations, Organizations, and Products, etc. It further extracts semantic meaning through the mapping to classes, attributes and relationships. This kind of

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parsing is quite similar to the natural language processing followed in modern applications. The compiled intent expression is further mapped to the DSL for a specific user or specific domain.

In the exemplar SD-WAN Service intent DSL format suggested in the MEF community, the DSL schema consists of the keywords to denote the start/stop of entity definition blocks, restricted domain-specific keywords (such as SD-WAN Edges, Connectivity, etc.), a place holder for user input (or variables), and comment blocks.

1.2.1. Context of use and relevance for Intent Meta-Modeling

MEF restricted DSL is simple and straightforward in its representation by defining a set of keywords for a specific domain and catering to a specific set of users that can be translated or mapped to system-level policies. However, this simplicity needs to be examined with the requirement for reusability, interoperability, and applicability across wider scenarios to avoid the proliferation of multiple variations/versions of such restricted DSLs as well as specialized DSLs to meet specific needs. Additionally, the exemplar formats suggest leverage on a Lexicon of keywords, and management of such a lexicon may be an overhead unless it is handled by a centralized authority globally. MEF 71 initial contributions also indicate an evolution from restricted DSL to an advanced ontology and lexicon-based intent expression as well as the incorporation of domain-specific information model along with the ontology. In this case, an intent compiler is used to compose the semantic context by referring to the intent ontology and the input received from the consumer in restricted natural language format.

1.3. ETSI ZSM Dynamic Service Descriptor

ETSI ZSM 005 (Means of automation) gives reference to the intent-based modeling concept as one of the principles for the “means of automation”. The specification also refers to intelligent orchestration as a replacement for classic orchestration which can generate prescriptions at runtime to figure out the appropriate system state taking into consideration the current context.

ETSI ZSM 011 (Intent driven autonomous networks; General Aspects) which is still in the early draft stage has a placeholder for intent meta-model which is a *possible technology-agnostic meta-model that can be used for intent specification within the ZSM framework.* Additionally, the draft also has a placeholder for documenting *the domain-specific information models that can be used to specify the different intents to be used between the different entities.*

At a high-level ZSM 005 differentiates between policies and intent – policies as concrete functions to take decisions and intent as higher-level goals and benefits, further policies translate intent into concrete network setup. It is also mentioned that intent-based modeling is a synonym for goal-based policy refinement, for example, CFS with certain quality or behavior can be seen as a goal. The key difference with traditional orchestration is the presence of intent-graph - CFS object along with the behavior (policy) for composition (relationship) at runtime. The intelligent engine follows the policies to build CFS -> RFS -> Resource objects.

ZSM 005 further suggests the model description needs to capture the entire semantics of the model, which in other words is called the “reason behind the model” that is used by the intelligent orchestrator to create prescriptions at runtime. While the format of such a model is not mentioned in this specification, new terminology is coined to capture the Service model and the behavior aspect which may help the intelligent orchestrator to derive the runtime prescriptions – this is referred to as Dynamic Service Descriptor (DSD). Further, it is noted that

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the behavior aspect of the service model is captured as policies. So essentially the DSD would compose the Service objects, relationship graph, and behavior policies. At run-time the state transition of the service objects may be governed by the behavior policies and the relationship graph may influence the creation of service hierarchies. To summarize, according to ZSM 005, DSD forms the basis for intent wherein a graph of service objects is formed, and each service object is requested by another service object and such request is made on a service object.

1.3.1. Context of use and relevance for Intent Meta-Modeling

ZSM 005 and ZSM 011 tend to give a mixed view on the way intent is modeled. Both specifications do not indicate the intent meta-model format or how this can be leveraged for expressing different types of intent across domains.

While ZSM005 gives a new descriptor concept (DSD) which includes packaging of behavior/semantic aspect of the model to be used by the orchestrator as well as the relationship, it still looks to be low-level detail that cannot be composed without specialized operational knowledge (especially the behavior aspect). ZSM011 is in the early draft stage and currently does not indicate a specific intent meta-modeling approach.

1.4. ETSI Generic Autonomic Networking Architecture (GANA)

Intent Representation and Meta-Modeling approach

The ETSI GANA Framework (ETSI TS 103 195-2) being a truly generic reference model for Autonomic Networking, Cognitive Networking and Self-Management of Networks and Services, accommodates any (meta)-modeling languages for Intents and does not restrict to a specific language for (meta)-modeling of Intents. For the simple reason that it gets to be decided at the time of GANA instantiation onto a particular reference implementation-oriented network architecture and its associated management and control architecture, the framework(s) for use in (meta)-modeling of Intents in the resultant "*GANA autonomics*" *enabled* reference network architecture and its management and control architecture. The value of ETSI GANA is in its ubiquitous pervasive applicability to a wide range of ICT network architecture scenarios and cases (the current architectures and future network architectures as well), being a generic blueprint based framework for implementing autonomics, cognition and self-management capabilities for networks and services.

For example, a GANA instantiation onto a Broadband Forum (BBF) network architecture scenario and its associated management and control architecture creates a "*GANA autonomicity*"*-enabled* BBF architecture scenario (see for example ETSI TR 103 473 on GANA onto BBF architecture scenarios, one of several GANA instantiation cases). Another example of a GANA instantiation is the GANA instantiation onto the 3GPP Backhaul and EPC Core Network (ETSI TR 103 404). Other example GANA instantiations include ETSI TR 103 495, ETSI TR 626. What it means is that in all these various GANA instantiations any (meta)-modeling framework for Intents supported by the target architecture upon which GANA Functional Blocks and Reference Points have been instantiated (e.g., in the BBF architecture case or 3GPP Case, etc.) should be applied.

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1.4.1. Context of use and relevance for Intent Meta-Modeling

Therefore, what the ETSI GANA Framework addresses rather, when it comes to Intents and Intent Based Networking (IBN) are the following aspects:

1. **Types of Intents**: The ETSI TR 103 195-3 describes various types of Intents and where they can be used in an Autonomic Network (AN), namely: (1) *Vertical Downstream Intent, (2) Vertical Upstream Intent, and (3) Horizontal Intent (Cross Domains)*
2. **A Framework by which Intents are to be handled in GANA** is described in ETSI TS 103 195-2 and complementarily in ETSI 5G PoC White Paper No.4: https://intwiki.etsi.org/images/ETSI_5G_PoC_White_Paper_No_4_v3.1.pdf
3. **How Intents and other Inputs for use in Network Governance** via the Governance Interface of the Autonomic Network (AN), such as High Level Business Goals for the Network, Service Profiles and SLAs, Network Service Definitions/Graphs, Service Chains/Graphs, and Profiles/Policies, are all used to generate a composite Governance Input called "Network Profile" that encapsulates all such items as structured and packaged inputs to the Autonomic Network (AN). To quote ETSI TS 103 195-2: "*High Level Business Goals for the Network, Service Profiles and SLAs, Network Service Definitions/Graphs, Application Intents and Profiles/Policies, are all used to generate a Network Profile consisting of information such as technical goals/objectives of the network, network service profiles, network service policies, application intents and profiles, configuration data for network elements (NEs), and other types of information and data that could be necessary to create or generate and store into the inventory in form of configuration files or model descriptions (e.g. YANG models).With the aid of a G-MBTS Translation and Network Profile Generator Tool the human operator generates Low Level Config Policies and Config-Data or Models consisting of Policies, Goals, Intents, Service Definitions, and Configuration-Data encapsulated by a Network Profile Skeleton that may be generated in a format like XML, and any additional Config-Files or Models (e.g. YANG models) required. The Knowledge Plane DEs algorithms shall operate in such a way that they are governed (by the goals and policies) or are aware of such items encapsulated by the Network Profile (i.e., the DEs take into consideration the items in the Network Profile). The Network Profile also contains Node Profiles for individual NEs (GANA nodes) that may be expressed in a format such as XML should be complemented with Node Config Files in some formats accepted by NEs' configuration agents.* "
4. **Roles that Ontologies could play at the Network Governance Interface of an AN**: The ETSI 5G PoC White Paper No.4 (https://intwiki.etsi.org/images/ETSI_5G_PoC_White_Paper_No_4_v3.1.pdf) discusses the possibility to use "a business level language" that could help the Network Operator to express what is needed from the autonomic network, with consideration that "such a business language shall be semantics-oriented and may be modeled by the use of an ontology to add semantics and enable machine reasoning on the goals". The White Paper further mentions the need for translation of high-level ontology-based business language to Service Profile and Network Profile. These profiles are distributed for policy execution and enforcement at Network elements to network functions.
5. **Integration of Automated Management and Autonomic Management as two domains, and definition of Network Governance Interface through which Intents and other Inputs can be used to govern the Autonomic Network** (AN): https://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp16_gana_Ed1_20161011.pdf

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1.5. ETSI ENI Intent Representation and Translation

ETSI ENI System Architecture specification ENI 005 gives reference to three types of policy – declarative policy, imperative policy, and intent policy. These policies are defined as follows:

- *Declarative policy: a type of policy that uses statements from formal logic to describe a set of computations that need to be done without defining how to execute those computations.*
- *Imperative policy: a type of policy that uses statements to explicitly change the state of a set of targeted objects.*
- *Intent Policy: a type of policy that uses statements from a restricted natural language (e.g., an external DSL) to express the goals of the policy but does not specify how to accomplish those goals.*

Further, the ENI System Architecture specification introduces the Unified Policy Information Model which is based on MEF Policy Model that serves as *a common language that enables concepts used by different policy authors to be mapped to equivalent concepts in other levels.* As per this model, all types of policies are abstracted and represented in terms of policy statements and each statement is represented in terms of policy clauses.

ENI gives multiple language choices for writing different types of policies:

- Controlled Language: *a restricted version of a language that has been engineered to meet a particular purpose. Example* – a restricted form of natural languages such as English which uses a subset of grammar and vocabulary.
- Domain-Specific Language: *a small human-understandable language that uses a higher level of abstraction to communicate and configure software systems for a particular application domain*.
- General Purpose Language: *a programming language used by professional programmers and developers that can address a wide variety of problems and domains*.

As per the ENI specification, the difference between DSL and GPL is that DSL is typically designed to be used by the non-programmers that are experts in the domain which DSL is addressing. Additionally, DSL is classified as internal vs external wherein the internal DSL does not require a specialized compiler/interpreter, whereas external DSL requires the development of own grammar that may require specialized compilers/interpreters. ENI architecture specification recommends the use of external DSL for representing intent policies for enabling non-programming users to define/use the policies. Additionally, it is recommended to define standard intent grammar specifications for intent policies. It also cautions against using controlled natural language as it requires significant effort to develop and maintain.

ETSI ENI Specification ENI 008 (Intent Aware Network Automaticity) explains in detail the process of intent translation using the "intent translation" functional block as part of the Policy Management. The translation is carried out because the intent policy rule for one constituency may be quite different in structure and content compared to other constituencies. The intent translation functional block is expected to *perform lexical analysis, syntactic analysis, semantic analysis, and augmentation, either parsing or compiling and, optionally, interpretation of the Intent Policy*. Intent translator derives meaning out of the intent and converts it into the *desired format executed internally by the ENI system or generates a recommendation to be used by assisted systems.*

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At the time of this writing, there is a new work item "ENI 013 – Intent Policy Model Gap Analysis" being initiated in the ETSI ENI workstream which is expected to evaluate different methods for intent policy modeling, mostly those driven by other SDOs and also expected to provide a recommendation on way forward.

1.5.1. Context of use and relevance for Intent Meta-Modeling

ETSI ENI specifications give a comprehensive view on intent management based on the intent policy, covering the variants, translation mechanism, how it may be consumed by the ENI and assisted systems, etc. There are also directions on representing the intent policy as an extension of the MEF Policy Model, however, there is a lack of clarity currently on the intent DSL or the meta-model based on which intent DSL will be developed. But from the details, it looks like the direction is to use a restricted DSL similar to the approach followed in MEF. As stated above, ENI also cautions against using a controlled natural language instead of restricted DSL due to the overhead in developing and maintaining such language. The recommendations in ENI-013 (work in progress) may provide more clarity on how an intent meta-model can be used as per the directions in the ENI specification.

1.6. 3GPP Intent Modeling Approach

3GPP TR 28.812 specification "Study on scenarios for Intent driven management services for mobile networks" describes intent-driven management concepts, scenarios, and recommendations for the way forward on standardization. One of the concepts covered in this specification is an intent expression which is a piece of information that includes the objective and related details. The specification also details the responsibility of the "intent-driven Management Service Provider" to translate the intent expression information to services, network operations, and related resource requirements.

In TR 28.812 a high level representation of Intent Expression is given as a combination of <*IntentDrivenAction*> and <*IntentDrivenObject*>. Here *IntentDrivenObject* gives the management object information according to intent requirement, whereas *IntentDrivenAction* provides abstract and simplified network and operation information according to intent requirements. The *IntentDrivenObject* is composed of <*intentDrivenObjectName*> and set of <*IntentDrivenObjectProperties*>, similarly <*IntentDrivenAction*> may consist of the <*IntentDrivenActionName*> and set of <*IntentDrivenActionProperties*>.

Further to the intent expression concept the 3GPP specification details the intent translation as well as dimensions of the intent-driven framework. One of the dimensions being mentioned is the Language of intent, which can be:

- *Native machine language: expressed in native machine languages such as computer code or binary code*
- *Imperative: expressed in simple statements mainly describing the "How" part than the "What"*
- *Declarative: expressed without defining the control flow*
- *Natural: expressed in human language*

Furthermore, the specification also differentiates Policy-driven management and intent-driven management. Here, *an intent is identified as the state where we want the entity to be* and policy *as the necessary step to get to this state*.

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1.6.1. Context of use and relevance for Intent Meta-Modeling

While the 3GPP 28.812 specification does not give detailed intent meta-modeling guidelines, the representation of intent expression as a combination of intent object and intent action gives some direction expected for 3GPP specific scenarios. However, expression of intent as the desired state (intent object) and abstract action on an object (intent action) gives a notion that the consumer is aware of the object state and actions on an object, i.e., this is more aligned to a restricted DSL that can be applied for specific management scenario or domain. Unlike the ETSI ZSM and ENI specifications where different flavors of policy are expressed (one of those being intent policy), in the 3GPP specification, the difference between intent-driven and policy-driven management is identified. 3GPP specification also indicates policy-driven management as an evolutionary step towards intent-driven management. The specification does not indicate how the action & objective in the intent expression may map to the policy (to drive the management entity to the desired state).

In 3GPP specification 28.312 (Intent driven management services for mobile networks) which is still in the early stage (initiated during the Release 16 time frame), a placeholder section for intent categories based on management scenario types is given. This section is expected to give more details on the intent expression however, this is not available yet.

1.7. IETF Intent Classification Methodology

IETF draft on Intent Classification (draft-irtf-nmrg-ibn-intent-classification) discusses the network intent, methods to classify and encode intent, and intent taxonomy among other topics. Additionally, RFC 7575 (Autonomic Networking: Definitions and Design Goals) defines intent as an abstract high-level policy used to operate a network.

This IETF draft on classification also identifies two key aspects to classify intents – *solutions* and *actors*. i.e., the intent types vary based on the specific solution that it caters to – for example, Carrier Networks, DC Networks, Enterprise Networks; similarly, the intent types vary based on the actor as the actor requires different intent types based on use case and context.

The IETF draft further gives an intent classification methodology to create new intent classification from scratch and intent taxonomy (covering the intent solutions, intent user types, intent types, intent scopes, network scopes, abstractions, and lifecycle) that can be used along with intent classification methodology for various solutions.

1.7.1. Context of use and relevance for Intent Meta-Modeling

While the IETF draft (draft-irtf-nmrg-ibn-intent-classification) currently does not suggest any meta-modeling for intent, it gives clarity on the methodology to be used for classification of intent as well as helps to identify the key elements that constitute intent and considerations while preparing the intent for specific scenarios. The IETF draft highlights the need for different types of intents catering to different use cases and contexts depending on the solution or actor that it is being used with or other criteria being considered in the intent classification methodology. This may help in setting a base for DSL or models of intent.

1.8. IETF NEMO Network Intent Modeling Language

IETF draft draft-xia-sdnrg-nemo-language (NEMO (NEtwork MOdeling) Language) describes a domain-specific language based on an abstraction of network models and accommodates various operational patterns. IETF draft draft-zhou-netmod-intent-nemo describes a basic

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yang model for the network intent expressed through NEMO language. The yang model consists of basic building blocks for expressing network intent such as node, link, flow, policy, and intent batch which can be extended based on the use case requirement.

A detailed explanation of the model construct is beyond the scope of this document. The NEMO language is built around a set of basic network models abstracting the network demand and these demands can be for network resources or network behavior. The network is composed of three basic entities - Customer Facing Node, Connection, and Service Flow. To accommodate the network behavior expected by the end-user NEMO provides two types of constructs – information acquisition and control operation. The information acquisition construct provides two methods to get information about the network – Query and notification. Similarly, to control the network NEMO supports operations that can be associated with any entity such as Node or Service Flow operation.

1.8.1. Context of use and relevance for Intent Meta-Modeling

As noted above NEMO language has limited scope and is primarily used for an abstract representation of network demand. The language accommodates both the object and behavior part of the intent that requires a specialized intent engine to translate to the low-level constructs as well as to build the end-to-end network context based on the input. A reference yang model for the NEMO language is available in draft draft-zhou-netmod-intent-nemo which can be used as a meta-model. The model also allows the extension of basic building blocks to accommodate user-specific objects or behaviors. As NEMO has restricted constructs and limited scope it can only be treated as a restricted intent DSL for a specific layer and may not be relevant for wider intent meta-model requirements.

1.9. ONAP Intent-Based Network Proof of Concept

ONAP introduced the intent-based network management capability in the Guilin Release with the implementation of the IBN proof of concept (reference), which is roughly based on the 3GPP 28.812 intent-driven management system reference architecture. The ONAP Guilin release IBN PoC showcased a vertical industry use case for smart warehouse management. The PoC introduces an intent framework which *takes high-level business goal as input, converts it to necessary network configurations and applies the network changes via network automation and/or network orchestration. The framework also monitors the status of the network under control, to verify that the intent is being met and takes corrective actions when desired intent is not met*. The intent framework consists of four functional blocks.

- intent management: Provides a northbound interface for consumers, including intent schema and intent management
- intent translation: Converts higher-level business goal to network-level configuration or orchestration request
- intent decision and execution: Decides which candidate intent solution shall be executed in response to a request by a managed entity and executes the translated intent solution by sending an appropriate request to a managed entity or to another intent framework.
- intent database: Stores intent schema, intent instance, and intent knowledge

The ONAP IBN proof of concept uses the 3GPP recommended intent structuring format which at a high level consists of <IntentDrivenAction> and <IntentDrivenObject>. Refer to the 3GPP Intent Modeling Approach above for more details about these entities.

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1.9.1. Context of use and relevance for Intent Meta-Modeling

While the ONAP IBN proof of concept is experimental as of the Guilin Release, it gives a reference implementation roughly based on an SDO recommended approach. The current scope and applicability are limited for the particular scenario being considered. However, the approach being followed indicates a use case specific intent DSL to be defined and used for intent translation, decision, and execution. The translation mechanism is also based on simple lexical and grammatical analysis without any immediate scope for knowledge-based semantic translation. ONAP IBN project has defined an enhanced set of capabilities as road map items for upcoming releases which includes general intent modeling as well as enhancement of data model for specific use cases.

1.10. O-RAN

O-RAN WG2 Specification A1 interface- General aspects and principles defines RAN intent and different types of policy such as imperative, declarative and intent policy. The RAN intent is defined as "*Expression of high-level operational or business goals to be achieved by the radio access network, allowing an operator to specify the desired SLAs that RAN needs to fulfill for all or a class of users in a given area over a period of time*". The definition of different types of policies is based on ETSI GR ENI 004. While the RAN intent definition is currently out of scope it is expected that the Non-Real Time RAN Infrastructure Controller which is part of the Service Management and Orchestration component of the O-RAN Architecture, is responsible for receiving the RAN Intent and then translate to an internal policy such as over A1 interface. But until the scope of the RAN intent and the functional capabilities are clearly defined it will be too early to speculate.

1.10.1. Context of use and relevance for Intent Meta-Modeling

As explained above O-RAN currently does not provide any intent meta-model specification for RAN intent. Only the need for the RAN intent at a system level is expressed. So, it is assumed that the realization of such a RAN intent is expected to be implementation specific. From the definition of RAN intent, it is assumed that the representation of the intent is more of a Domain specific language limited to RAN domain which expresses the goal in terms of SLA and RAN needs.

1.11. Abbreviations

Term	Expansion
SDO	Standard Definition Organization
CFS	Customer-Facing Service
RFS	Resource-Facing Service
CSP	Communication Service Provider
DSL	Domain Specific Language
ENI	ETSI Experiential Networked Intelligence

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Term	Expansion
ZSM	ETSI Zero-touch Service and network Management
RAN	Radio Access Network
SD-WAN	Software Defined Wide Area Network
GANA	ETSI Generic Autonomic Network Architecture

1.12. Definitions

Meta-Modeling : analysis, construction and development of the frames, rules, constraints, models and theories applicable and useful for modeling a predefined class of problems (more details here)

Ontology : As per Wikipedia ontology encompasses a representation, formal naming and definition of the categories, properties and relations between the concepts, data and entities that substantiate one, many, or all domains of discourse. W3C considers vocabulary and ontologies as synonyms, wherein ontology as a more formal and complex collection of terms and vocabulary as used in very loose sense. Vocabularies define concepts and relationships (also referred to as "terms") used to describe and represent an area of concern. In simple terms ontology is a way of showing the properties of a subject area and how they are related, by defining a set of concepts and categories that represent the subject.

Knowledge Graph: a collection of interlinked descriptions of entities – real-world objects and events, or abstract concepts (more details here) . As per Wikipedia, knowledge graph is a knowledge base that uses a graph-structured data model or topology to integrate data.

Semantic web : Extension/Evolution of World wide web through standards set by W3C (more details here)

1.13. References

Reference	Link
W3C Resource Description Framework(RDF) Wiki	https://www.w3.org/RDF/
W3C Simple Knowledge Organization System (SKOS)	https://www.w3.org/2001/sw/wiki/SKOS
W3C Web Ontology Language (OWL)	https://www.w3.org/2001/sw/wiki/OWL
W3C RDF Schema (RDFS)	https://www.w3.org/wiki/RDFS

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Reference	Link
MEF Intent Based Orchestration Project	https://wiki.mef.net/pages/viewpage.action?pageId=63181121
ETSI ZSM Means of Automation ZSM005	https://www.etsi.org/deliver/etsi_gr/ZSM/001_099/005/01.01.01_60/gr_ZSM005v010101p.pdf
ETSI 5G PoC White Paper No.4	https://intwiki.etsi.org/images/ETSI_5G_PoC_White_Paper_No_4_v3.1.pdf
ETIS Generic Autonomic Network Architecture; Part 2: An Architectural Reference Model for Autonomic Networking, Cognitive Networking and Self-ManagementETSI TS 103 195-2	https://www.etsi.org/deliver/etsi_ts/103100_103199/10319502/01.01.01_60/ts_10319502v010101p.pdf
ETSI GANA White Paper No:16 : GANA - Generic Autonomic Networking Architecture	https://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp16_gana_Ed1_20161011.pdf
ETSI Experiential Networked Intelligence (ENI); System Architecture	https://www.etsi.org/deliver/etsi_gs/ENI/001_099/005/01.01.01_60/gs_ENI005v010101p.pdf
ETSI Experiential Networked Intelligence (ENI); InTent Aware Network Autonomicity (ITANA)	https://www.etsi.org/deliver/etsi_gr/ENI/001_099/008/02.01.01_60/gr_ENI008v020101p.pdf
3GPP TR 28.812 specification Study on scenarios for Intent driven management services for mobile networks	https://ftp.3gpp.org//Specs/archive/28_series/28.812/28812-100.zip
3GPP TS 28.312 Intent driven management services for mobile networks	https://www.3gpp.org/ftp/Specs/archive/28_series/28.312/28312-040.zip

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Reference	Link
IETF draft Intent Classification	https://datatracker.ietf.org/doc/draft-irtf-nmrg-ibn-intent-classification/
IETF RFC 7575 Autonomic Networking: Definitions and Design Goals	https://datatracker.ietf.org/doc/html/rfc7575
IETF Draft NEMO (NEtwork MOdeling) Language	https://datatracker.ietf.org/doc/html/draft-xia-sdnrg-nemo-language-04
IETF Draft YANG Data Models for Intent-based NEtwork MOdel	https://datatracker.ietf.org/doc/html/draft-zhou-netmod-intent-nemo-00
ONAP Intent Based Network management Proof of concept	https://wiki.onap.org/display/DW/Use+Case+Realization+Call%3A+Feb+8%2C+2021?preview=%2F93001716%2F93011258%2F20210208_Intent+Framework+and+Intent+Modeling_UCRealization.pdf
O-RAN WG2 Specification A1 interface- General aspects and principles	https://oranalliance.atlassian.net/wiki/download/attachments/182976589/O-RAN.WG2.A1GAP-v02.02.docx?api=v2

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2. Administrative Appendix

2.1. Document History

2.1.1. Version History

Version Number	Date Modified	Modified by:	Description of changes
1.0.0	28-May-2021	Alan Pope	Initial Release

2.1.2. Release History

Release Status	Date Modified	Modified by:	Description of changes
Pre-production	28-May-2021	Alan Pope	Final edits prior to publication
Production	26-Jul-2021	Adrienne Walcott	Updated to reflect TM Forum Approved Status

2.2. Acknowledgments

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