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Improved operator experience through Experiential Networked Intelligence (ENI)

Introduction - Benefits - Enablers - Challenges - Call for Action

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Executive Summary

This white paper draws attention to the need to improve the operator experience. The use of artificial intelligence (AI) techniques in the network management system could help solve some of the problems of future network deployment and operation based on the "observe-orient-decide-act" control model. This enables the system to adjust the offered services based on changes in user needs, environmental conditions and business goals. This encompasses open intelligent functionality for network configuration and management. It provides inputs and objectives to progress the industry on Intelligent Policy-based management.

The main challenges may be stated as:

- automating complex human-dependent decision-making processes,
- determining which services should be offered, and which services are in danger of not meeting their Service-Level Agreements (SLA), as a function of changing context,
- defining how best to visualize how network services are provided and managed to improve network maintenance and operation, and
- providing an experiential architecture (i.e., an architecture that uses AI (Artificial Intelligence) and other mechanisms to improve its understanding of the environment, and hence the operator experience, over time).

The ETSI Industry Specification Group (ISG) on Experiential Networked Intelligence (ENI) focuses on improving the operator experience, adding closed-loop artificial intelligence mechanisms based on context-aware, metadata-driven policies to more quickly recognize and incorporate new and changed knowledge, and hence, make actionable decisions. ENI will specify a set of use cases, and the generic technology independent architecture, for a network supervisory assistant system based on the 'observe-orient-decide-act' control loop model. This model can assist decision-making systems, such as network control and management systems, to adjust services and resources offered based on changes in user needs, environmental conditions and business goals.

ENI intends to perform the work in three phases; phases 1 & 2 are planned for the initial ISG period of two years, with an eventual phase 3 being planned after the ISG renewal (2 years). These phases reflect the main goals as laid out above.

The value of the ISG ENI is that it will define a functional block architecture that uses metrics in a standards-based intelligent policy engine to orchestrate and choreograph business services. It will develop "Automated Network Operation" with progression to closed loop machine learning and Artificial Intelligence.

ETSI is the ideal organization to undertake and provide leadership for this work. An Industry Specification Group closely linked to model-driven engineering would benefit the industry.

1 Introduction

1.1 Perspectives on industry progress

The ultimate goal of development of science and technology is to improve the human experience, i.e. to make machines more suitable for humans to use, and to simplify the human-machine interaction, by letting the machine do more by improving the user experience with greater use of Artificial Intelligence (AI).

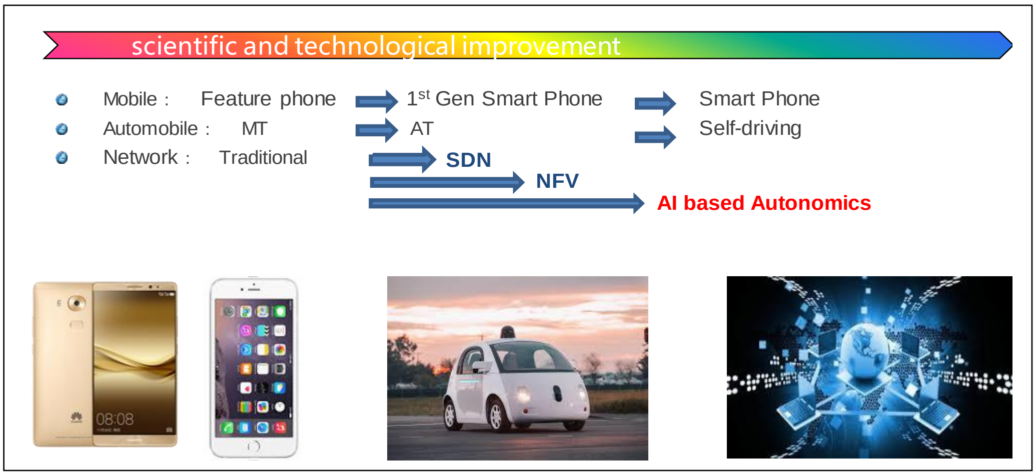

Figure 1: Technology Evolution

As illustrated in Figure 1 above; over the last two decades, enormous transitions have been made in the end user experience from dedicated voice and text mobile telephony, utilizing international standards. This was achieved by migration from company propriety operating systems to a global open software market for tablets and smart phones, and user customization of data services based on a reliable market for apps. The near future promises significant automation gains across markets, including automobile travel and automation using communications. We see the rise of improved driving features and the use of communications technology whilst traveling. With automated vehicles, the use of smart on-board technology, greater access to the internet and app market the opportunity for convergence appears. The expectation of Internet of Things (IoT) and reliable self-driving vehicles is not very far away.

Where is network evolution going? Traditional networks are still greatly in evidence; we see signs of Software Defined Network (SDN) effectiveness and the promise of Network Functions Virtualization (NFV). These two technology domains will be further strengthened with orchestration and componentization; however, the open equipment and network management revolution is still anticipated. Intelligent network management and re-configuration may be expected, in particular due to the increasingly dynamic evolution of the network as well as the end users. Freedom for operators to enter policy intent and allow the network to configure, optimize and run to the best of its efficiency is in many cases a dream.

A key pain point when operating communication equipment is the need for man-machine interaction. The complex experience, human-dependent decision, and complex manual configuration, result in low resource utilization and delays in deployment.

1.2 Objectives

The use of artificial intelligence (AI) techniques could help solve some of the problems of future network deployment and operation based on the “observe-orient-decide-act” control model. This enables the system to adjust the offered services based on changes in user needs, environmental conditions and business goals.

2 Rationale

2.1 Challenges and opportunities

Human-machine interaction is error-prone and operators are worried about the increasing complexity of integration of different standardized platforms in their network and operational environment; this is due to the vast differences inherent in programming different devices as well as the difficulty in building agile, personalized services that can be easily created and torn down. These human-machine interaction challenges are being considered by operators as barriers to reducing the time to market of innovative and advanced services. Moreover, there is no efficient and extensible standards-based mechanism to provide contextually-aware services (e.g., services that adapt to changes in user needs, business goals, or environmental conditions).

These and other factors contribute to a very high OPerational EXpenditure (OPEX) for network management. Operators need the ability to automate their network configuration and monitoring processes to reduce this OPEX. More importantly, operators need to improve the use and maintenance of their networks. In particular, this requires the ability to *visualize* services and their underlying operations so that the proper changes can be applied to protect offered services and resources (e.g., ensure that their Quality-of-Service (QoS) and Quality-of-Experience (QoE) requirements are not violated). If such visualization could be provided, then operators would be better able to maintain their networks.

The associated challenges may be stated as:

A. automating complex human-dependent decision-making processes,

B. determining which services should be offered, and which services are in danger of not meeting their Service-Level Agreement (SLA)s, as a function of changing context,

C. defining how best to visualize how network services are provided and managed to improve network maintenance and operation, and

D. providing an experiential architecture (i.e., an architecture that uses AI (Artificial Intelligence) and other mechanisms to improve its understanding of the environment, and hence the operator experience, over time).

The ISG ENI (Experiential Network Intelligence) will have the following standardization goals:

a) describe answers to the above challenges to improve the experience of operators and network administrators focusing on improved policy and automation,

b) specify a policy-based, model-driven architecture that defines functionalities to assist orchestration on adapting the services to changing user needs, business goals, and environmental conditions at scale,

c) propose an approach that enables the networked experience to be measured and presented to operators and other stakeholders,

d) propose recommendations to other SDOs on how this architecture may be realized,

e) propose a data collection and an analyzing mechanism as a requirement for providing the End-to-End (E2E) network diagnosis ability, including automatic fault detection, diagnosis and prediction, to be used by the intelligent engine.

The aforementioned challenges will require advances in network telemetry, big data mechanisms to gather appropriate data at speed and scale, machine learning for intelligent analysis and decision making, and applying innovative, policy-based, model-driven functionality to simplify and scale complex device configuration and monitoring. Figure 2 below illustrates the data distribution process: data collection aims to merge these data and publish them to the data distribution layer. The data distribution layer uses a publish/subscribe model, then analytics applications can subscribe to obtain the data needed. The use of a model-driven system that supports policy-based functionality will provide a better operator experience through providing more powerful and consistent service and resource management and orchestration mechanisms, while concurrently enabling business needs to be translated into customer services, thereby maximizing resource efficiency and automation. This combination of technical advances will result in an architecture (to be specified as facilities and advances) that can efficiently present, and enable the automation and optimization of the networked experience for operators and other stakeholders.

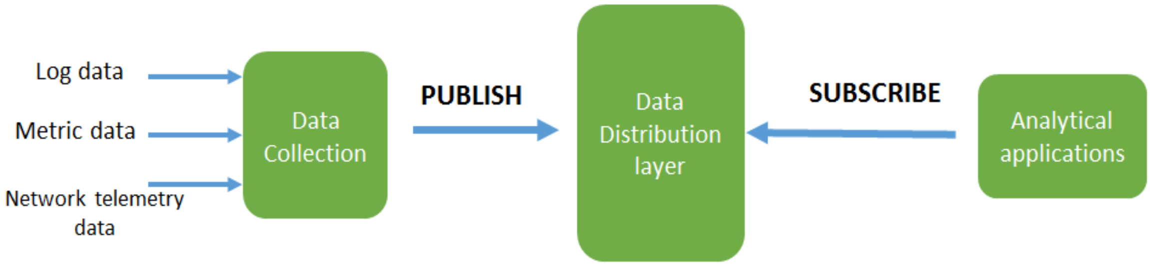

Figure 2: Data Distribution Process

ETSI is seen to be the ideal organization to undertake and provide leadership for this work. Whilst service and resource specifications and standards are actively being progressed, these efforts are distributed across multiple Standards Developing Organizations (SDOs) and do not address operator experience. An Industry Group that is closely linked to model-driven engineering would benefit the industry. This work is proposed to be studied in an Industry Specification Group called Experiential Network Intelligence (ENI).

An ETSI Industry Specification Group (ISG) enables the requirements of operator use cases to be used as an anchor for cooperation across SDOs. This work will be used to define a model-driven architecture that shows how operators can measure operator experience, and incorporate those changes to guide the adaptation of services and resources in a closed-loop process. ENI is built on the premise that the business must be able to dynamically program the infrastructure to deliver resources and services that dynamically adapt to changing user needs, business goals, and environmental conditions. Furthermore, this must be done without burdening the operator, and transparently to the end-user.

An ETSI ISG allows priority work to be scoped and undertaken, with an open legal and cooperative framework linking to existing SDOs and open source organizations. An ISG allows the regular participation of non-ETSI members and has time-limited objectives to be reviewed.

2.2 Comparison to existing related SDOs

Work has been undertaken in many SDOs, usually based on specific network environments, as illustrated in Table A-1 (Policy-Service-Resource Management in various SDOs), in the Annex.

Solving the problem of technology development in isolation will require a new inter-SDO cooperation effort. A critical first step in providing a better operator experience is to use a model-driven system that supports policy-based orchestration. This will provide a better operator experience through providing more powerful service and resource management and orchestration mechanisms. See the “Annex: Analysis of work in other SDOs” for further details. Hence, an ENI engine that performs this model-driven functionality, using policy management, needs to be studied.

2.3 Value of ISG ENI

The value of the ISG ENI is that it will define a functional block architecture that uses metrics in a standards-based intelligent policy engine to orchestrate and choreograph business services. An example is the management of a policy sold between businesses, where a platinum user gets priority service. It will develop “Automated Network Operation” with progression to closed loop machine learning and Artificial Intelligence. This engine provides two important benefits.

1. to measure and quantify the operation and performance of the resources, network and supported services and
2. to enable the optimization and adjustment of operator experience.

This will improve the operator experience over time. This is critical when services and resources are modelled and choreographed to understand their behaviour elsewhere in the network. In particular, the use of closed control loops, augmented by machine learning and other AI mechanisms will assist operators to make controlled and consistent network-wide changes to improve the maintenance of their networks and networked applications. The architecture will record these decisions, along with the context in which they were made, to increase its understanding of both network operation and the goals of the operator running the network. The self-learning principle is key to improving operator experience, as it helps to translate what is important for an operator in a certain situation, to a form that that the system can understand. By doing such, it learns over time to propose and possibly automate optimal decision making.

The ENI architecture enables the network to adjust the offering of services and resources and as well the behaviour required to support that new service offering. Policies can be used to manage how services and resources interact with the environment to achieve a defined target. For example, policies can control the transition to a new state in a state machine, and the overall state machine is managed using a closed control loop. As seen in Figure 3 below ENI is envisioned to enable the deployment, administration & control of migration toward new functionalities, especially SDN & NFV.

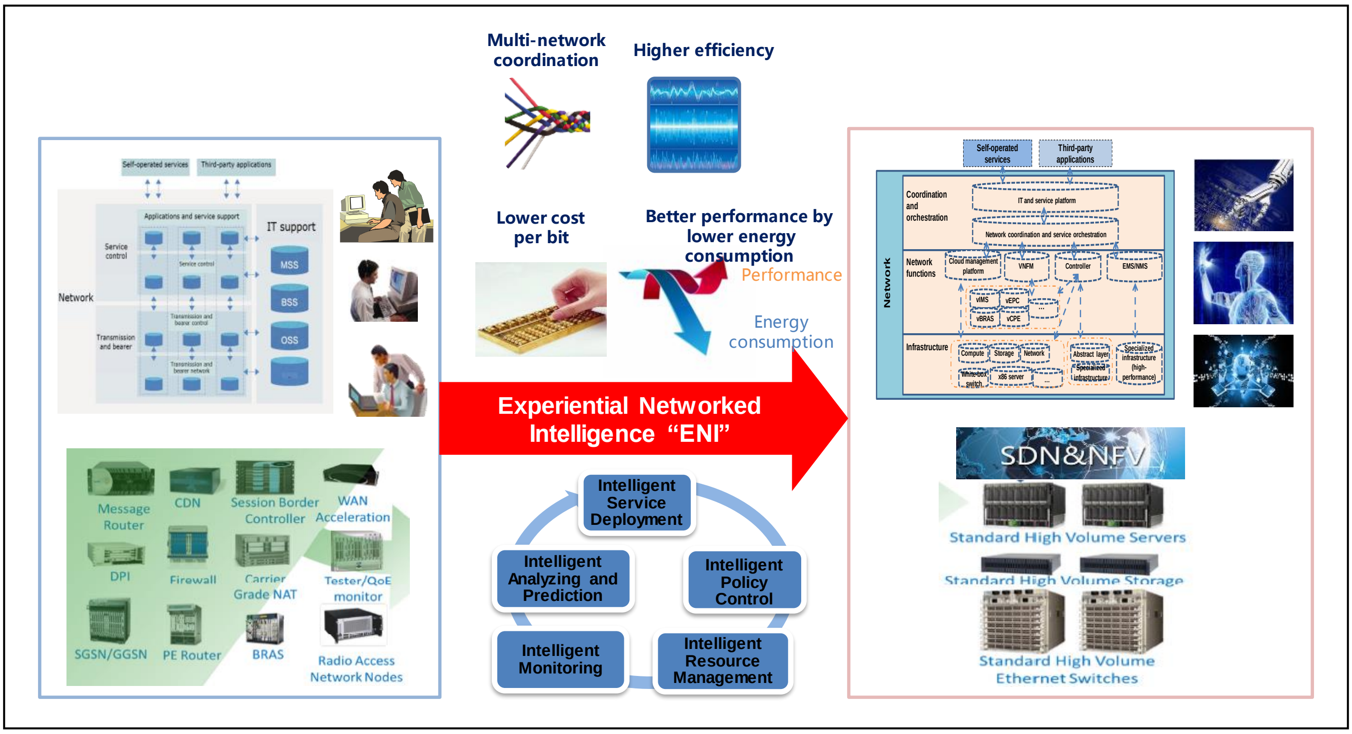

Figure 3: The vision of ISG ENI

Firstly, ENI enables personalized services to be provided to customers. This uses detailed policy models for innovative, model-driven orchestration that operators can employ to automate their business processes.

Secondly, it automates the operator's complex human-dependent decision-making processes by translating changing user needs, business goals and environmental conditions into closed-loop configuration and monitoring.

Thirdly, there are huge amounts of data on "inventory" databases detailing the structure of networks, today. The volume, velocity, and variety of data will continue to increase, making extracting actionable results ever more difficult. Big data and artificial intelligence can help deal with many of these problems, freeing the service expert to focus on fewer, more important, key problems.

This uses AI and other mechanisms to incorporate new knowledge, as well as changes to existing knowledge, in the model. This enables the model-based architecture to constantly involve and learn from its operation. This learning is key to improving operator experience, as it helps translate what is important to an operator in a situation to a form that the system can understand.

3 Scenarios and use cases

In this clause a number of ENI example scenarios and use cases are discussed.

3.1 Policy-driven IDC traffic steering

Operators are deploying Internet Data Centers (IDC) in Metropolitan Area Network (MAN) to provide multiple network accesses with load-balance and resilience. The services in IDC can access the network via different paths. This architecture suffers from several issues: difficult to optimize real-time traffic; little assurance during bursts such as big online sales; imbalance across multiple links. With policy-driven traffic steering, operator experience is improved by making the network more resilient, and services are improved in terms of maintaining QoS and QoE.

3.2 Policy driven IP managed networks

In the scenario of Home Access, the client sends the access request to Broadband Remote Access Server (BRAS) which configures several Internet Protocol (IP) address pools. These IP address pools allocate addresses to clients. Carrier Gate Network address translation (CGN), translates private addresses into public addresses. NAT configures several IP address pools as resources for public IP address translation.

This traditional IP management approach suffers from a low utilization ratio and poor sharing among equipment. Manual address allocation is cumbersome; and scripts are fragile and cannot adjust to dynamic network conditions. Policy enables more intelligent usage of address pools and automates the address allocation.

3.3 Network fault prediction

Traditional network fault analysis focuses on identifying faults. The drawback is that network performance and operators' experience already degrades when faults happen. We take one more step to predict network faults and incidents before they happen. One approach is to create a tendency curve by fitting historical network health data, and look into both the tendency curve and original curve (network health data actually-measured). When the tendency curve falls below a threshold, or the deviation between tendency curve and original curve exceeds a threshold, an alert will be raised. The operator experience is improved by proactively computing performance, reliability, and other trends in the network infrastructure, and addresses problems before they can degrade customer performance.

3.4 Fault localization and diagnosis

The high reliability and high availability required for carrier-class applications is a big challenge in virtualized and software-based environment where failures are normal. The interdependence between NFV's abstraction levels and virtual resources is complex. The dynamic characteristics of the resources in the cloud environment make it difficult to locate the fault. When a failure occurs on a layer, we can analyse relevant statistical data from multiple levels and find the possible points of failure, and rapidly locate the fault to recovery. Machine learning algorithms can extract patterns of faults and correlate various KPI indicators to find out the root cause.

This use case may also include the use of pattern matching and self-learning techniques to assist with issues that may occur in a wireless network. For example, using AI, a fault library that encapsulates the knowledge of operations and maintenance experts could be built. When an issue is detected the system can match the event with known items in the fault catalogue, and identify the likely root cause. The system is capable of self-improvement, and it can learn to identify new abnormal cases, and their root causes, after encountering them on a few occasions.

4 Proposed scope of ENI as an ETSI ISG

4.1 Scope of ENI - adaptive intelligence for enhanced networked experience

The purpose of ISG ENI is to define a context aware system using Artificial intelligence (AI) based on the "observe-orient-decide-act" control model. This enables the system to adjust the offered services based on changes in user needs, environmental conditions and business goals.

It is planned that the ISG ENI will be used as an embryonic industry group to define:

1. the requirements on operator experience in and across networks, and
2. an architecture that supports adaptive and intelligent service operation and management that provides acceptable operator experience.

4.2 ISG ENI deliverables

The ENI deliverables will enable the adjustment of services and resources as well as the behaviour required to support the new offering.

This will promote large-scale deployment of networks with evolving technologies such as SDN, NFV, and legacy network services by:

- defining use cases, requirements, and framework for the ENI engine as illustrated below
- integrating policy-based management and models to provide a model-driven orchestration process
- mapping business needs onto resources and services that are context-aware.

The objectives of the ISG ENI will be:

- to define the desired number of use cases / focused scenarios that illustrate a range of requirements on operator experience,
- to define a policy-based, model-driven architecture that defines functionalities to assist orchestration on adapting offered services and resources to changing context,
- to show how the above can improve in its knowledge and operation over time, and
- to define measures and quantification of operator experience; like user experience parameters for use in selecting ENI equipment.

4.3 Items for ENI to investigate

ENI will aim to be communications network independent, focusing on the context-aware intelligent engine in the management assistance plane. It plans to address, at least, the following issues:

- Interface specifications might be outside the scope of the ISG; however, in terms of ENI architecture, it might be useful to identify and use some key physical/logical interfaces. This may include identifying how the key entities of policy-based architecture would map on an actual network (e.g. cellular network entities like the PCRF in current LTE-Advanced networks).

- This white paper implies both 'reactive' and 'proactive' approaches to Policy management. ISG ENI will discuss and identify what are the key steps associated with 'observe-orient-decide-act' cycle in both cases.
- This white paper mentions different machine learning techniques; however, the ISG needs to study the associated complexity of each, particularly for real-time management services. In some cases, online learning might be better than offline learning approaches.

Agile and collaborative concepts focusing on telecommunication-centric networks, their vendors, customers and users may provide valuable and efficient alternatives. The industry is in the need of, and searching for innovative, cost-efficient and qualitative development and deployment methodologies (e.g. Joint Agile Delivery (JAD)).

4.4 Collaboration with other SDOs

At the initial phase, ISG ENI will NOT specify or standardize any interface. When gaps are found on existing interfaces that other SDOs have developed and ENI needs to use, then recommendations will be developed on how these gaps are solved. These gaps will be addressed in co-operation with the SDO that defined these interfaces. In the later phases, the ISG ENI considers the option to develop formal interface specifications, but only where (1) there is a clear need to do so, and (2) if these interfaces are not being developed by other SDOs.

The industry will value the ISG ENI if it shows how the defined architecture, policy-models and interfaces provide enhanced operator experience.

The ISG ENI will initially publish best practice documents that show how cross-SDO functional architecture, interfaces/APIs, and specific models or protocols, are capable of solving stated objectives/requirements. This is seen as very valuable both for operators and for vendors.

Note that collaboration between SDOs has not been overly successful to date, and that no SDO is currently focused on improving operator experience. The ISG ENI is planning a set of close liaisons, driven by joint members of each liaised SDO, to be developed to enable cooperation between SDOs as peer organizations. Open Source organizations will exist working on AI based automation assistants, symbiotic relationships need to be formed where specification organizations with learn from and contribute to these projects.

5 A possible ENI architecture to improve the operator experience

5.1 ENI: a use of policy-based model-driven engineering

It is difficult to adjust the services and resources offered by networks and networked systems when context changes. Closed control loops, whose behaviour is controlled using policy management, can be used to automate this process, as well as optimize it over time.

There is a need to ensure that networks with emerging technologies (e.g., SDN (Software Defined Networks), NFV (Network Functions Virtualization)), and Legacy Networks can be more easily and deeply integrated with each other, while handling the increased complexity related to them and future cloud-based and distributed networks. This will improve the operator experience in managing and using these diverse networks by eliminating the current "siloed" approach to managing different types of technologies in different networks. The key to this integration is the use of a model-driven, policy-based approach in the management and orchestration processes. The model serves as a lexicon, providing a dictionary, vocabulary, and semantics for any code, APIs, and languages that are built to model the orchestration processes. Furthermore, the model represents not just services and resources, but business concepts (e.g., customers and SLAs) as well.

It is planned that this architecture will use dynamic policy management to assist the orchestration of context-aware services and resources at scale in order to meet operator experience requirements. The requirements and architecture developed by the ISG ENI will apply to telco networks as well as data center networks.

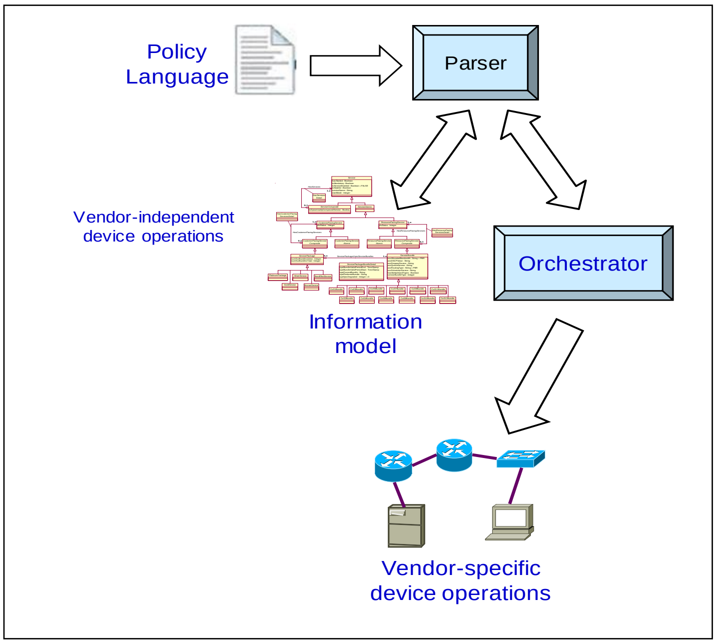

Figure 4: An illustrative example of using policy-based model-driven engineering

Figure 4 shows the key ENI functional entities and models, including policy (shown above). Also, the modelling of service, resource, customer, provider, and others. Policy language can be in the form of a Domain-Specific Language (DSL), a set of APIs, a web-based form, or console commands. The policy is parsed using the information model, and provides technology- and vendor-independent direction (e.g., configuration, monitoring, service activation, billing).

Model-driven engineering is a development methodology that uses models to define the functionality of managed entities and represent their behaviour. This methodology is critical for realizing improvements in operator experience. The result is not a single centralized-controller, -manager, or -orchestrator, but rather, a distributed system that manages and coordinates the delivery of an optimal set of services and resources depending on context. The underlying models represent business concepts, such as customers and SLAs, and associate them to the set of products, services, and resources that are available in the system. Policy management is then used to configure and monitor the services and resources.

The ENI architecture will show how these functional entities, including: APIs, and DSLs can be integrated. DSLs are simple but powerful languages that are specialized to a particular application domain. This provides runtime programmability in a vendor-neutral form. In particular, the ISG ENI focuses on intelligent service operation and management based on emerging technologies, such as big data analysis, analytics, and artificial intelligence tools, and on automating complex human-dependent decision-making processes. This will be realized by applying an innovative, policy-based, model-driven functional entity, denoted as ENI Engine, that understands the configuration and monitoring in accordance with changes in context. This provides the ability to ensure that automated decisions taken by the system are correct and are made to increase the stability and maintainability of the network and the applications that it supports. Moreover, it enables the translation of business needs into Services while avoiding low resource utilization.

Figure 5 shows an example of the functional components that can be incorporated in the ENI architecture. These functional components are the: (1) Inference System, that supports the Knowledge System and the Inference Engine, (2) Data Analysis that supports deep learning and machine learning and (3) Optimization that supports dynamic programming and the greedy algorithm.

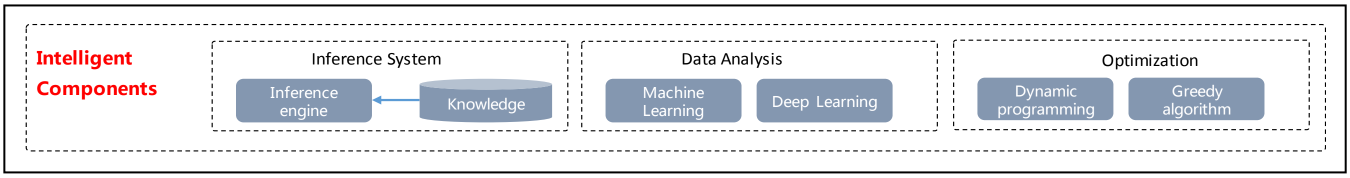

Figure 5: Examples of functional components incorporated in the ENI architecture

Note: The externally-visible characteristics and behaviour of the ENI functional entity will be addressed in the ISG. The ISG will not attempt to standardize the implementation of a policy engine, or of the NIE.

5.2 Example of improved operator experience across networks

ENI covers the intelligent operation and management of new evolving and traditional data plane devices for future intelligent devices. This is made more difficult by trying to harmonize the different network resource and configuration methods used in the variety of traditional networks as well as new evolving networks (e.g., SDN and NFV).

Note: there is not envisioned to be any change to the existing OSS/BSS. Network management will be augmented and improved by the use of this network intelligence. The term “traditional networks” covers many technologies, from ISDN, GSM, IPv4, Wi-Fi etc. ENI aims to be network independent.

There is a need to automate the SDN/NFV: policy - service - resource triple forces. The goal is to reduce operator operational expense, increase resource utilization, provide and test profitable services, enforce policies, thus to accelerate service delivery and promote operator experience; service & network management.

Work has been undertaken in many standards organizations, providing a disparate array of ideas that mutually rely on and impact each other. What is required is an overview enhancing development & outlining the improvements possible whilst utilizing agile/intelligent/flexibility principles. ETSI is seen to be the ideal SDO to undertake this work. Policy/service/resource specifications are distributed in many SDOs and their Working Groups. A unified view is required.

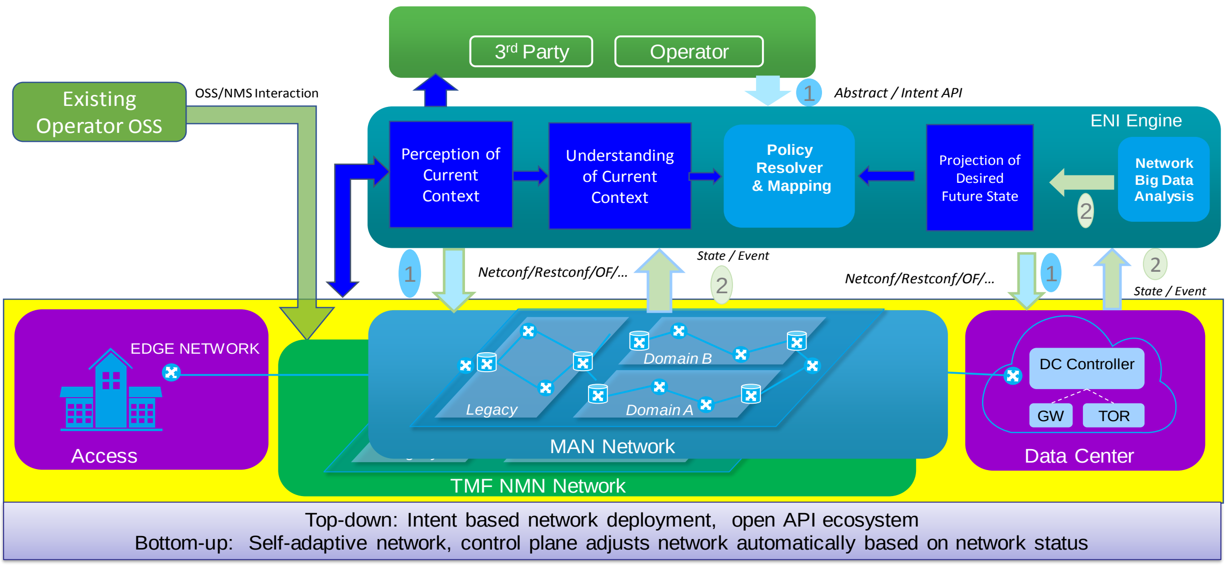

Figure 6: Conceptual Architecture of ENI

Figure 6 shows a possible concept of architecture within ENI, including two types of intelligence flows (i.e., top-down, and bottom-up). In this illustrative architecture, the ENI Engine layer adds network big data analysis to service/policy/resolver & mapping. It brings in intelligence from two directions: 1) top-down, intents passed from applications are translated into actionable network element level action/configuration, adapting to current network status; 2) bottom-up, network status/events are reported to the ENI Engine, and interpreted into understandable topology/measurements. Big data analysis technologies (such as machine learning, deep learning) can be applied to generate adaptive configuration and prescriptive analysis. Deep-learning as a technique will be discussed in the ISG.

Top-down: The ENI engine receives the abstract/intent API (see in the Figure 6) with the perception of the current context. This is translated into an actionable network element level decision or a configuration from an application. This result is projected with the understanding of it being context aware and the desired result. The decision and action is derived from the information using Big Data Analysis. The ENI engine then sends instructions to the underlying infrastructure via southbound interfaces.

Bottom-up: network status/events are reported to the ENI Engine. The Network Big Data Analysis component performs intelligent analysis on this huge volume data using technologies such as machine learning and deep learning, to generate a report and feedback to policies to facilitate the policy-driven service adjustment.

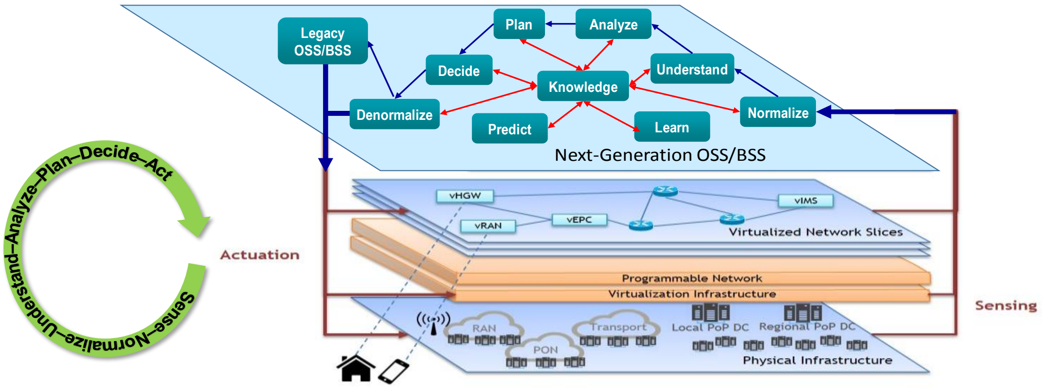

Figure 7: Closed loop of machine learning in ENI

Figure 7 shows how a closed loop of machine learning, by sensing the events and network conditions, can interact with intelligence functions and learn the responses to heal, fix and plan for new services and events. Actuation of functions in the network may follow.

5.3 Enablers for ENI

ENI would expect to use the deliverables from IETF SUPA WG, IETF L3SM WG and other upcoming service modelling WGs. It will also use and analyse the policy models in MEF, ONS etc. It will consider the orchestration architectures being developed in NFV and MANO.

6 Phasing proposal

The ISG ENI is envisioned to be a system that integrates analytics into closed-loop control of management and orchestration processes. It will be context-aware, and will analyse network telemetry to develop non-real-time and real-time actions to protect business goals and services. This will be done by integrating state-of-the-art technologies, such as Big Data, AI, and new modelling patterns for changing what is configured and monitored using model-driven engineering. The development of a standards-based reference architecture and Interface Reference Points are two of the unique contributions of ENI to the overall operator network management architecture.

The ISG ENI will have the following goals:

a) identify the requirements (e.g., from operators and network administrators) to improve operator experience,

b) define an architecture that is used to apply adaptive and intelligent service operation and management, which uses dynamic policy management to orchestrate service management and resource management at scale,

c) propose how the networked experience is measured and projected/presented to operators and other stakeholders, and

d) propose recommendations to other SDOs on how this architecture may be realized.

The envisaged Context Aware Intelligent Network Management system enables the steering of the usage of available network resources and services according to the real-time evolution of user needs, environmental conditions and business goals. Decisions taken by the Cognitive Network Management system rely on detailed information about the complex states of network resources and policies expressing operators' preferences. The unique added value of the ISG ENI approach is to quantify the operator experience by introducing a metric and the optimization and adjustment of the operator experience over time by taking advantage of machine learning and reasoning.

Different types of policies will be reviewed. These policies will be used to drive adaptive behavioural changes using various AI mechanisms.

ISG ENI will wherever applicable review and reuse existing standardized solutions for legacy and evolving network functions like e.g. resource management, service management, orchestration and policy management etc.

The ISG will include the definition of:

1. the requirements of the operator experience in and across legacy and virtualized networks including 5G networks, and
2. a model-driven architecture that supports adaptive and intelligent service operation through Cognitive Network Management to provide the required operator experience.

The ISG scope is limited to the functional description of the management plane. Interactions and policy descriptions will be matched with business processes and control layers in the network as described in the architecture in Phase 2.

Note: it is not envisioned to change the existing network operator legacy OSS/BSSs. The existing network management systems will be augmented and improved by using the cognitive networked intelligence.

6.1 Planned deliverables and delivery dates

The ISG ENI intends to perform the work in three phases; Phase 1 & 2 are planned for the initial ISG period of two years, with an eventual Phase 3 being planned after the ISG renewal (2 years).

Phase 1 (informative): Lasting approximately 12 months from launch, Phase 1 will describe use cases and requirements, definition of features, capabilities and policies.

In the Phase 1, ISG ENI will initially publish informative best practice documents (Group Reports (GRs)) that show how cross-SDO functional architecture, interfaces/APIs, and specific models or protocols address stated objectives/requirements. Additional informative Group Reports will also describe how policies can be managed and also illustrate service and resource management.

The following main tasks will be performed:

- Identify and describe appropriate use cases,
- Identify and describe the requirements for the improved operator experience,
- Carry out a gap analysis of work on context-aware and policy based standards,
- When gaps are found on existing interfaces that have been developed by other SDOs and that ISG ENI needs to re-use, then the recommendation on how these gaps should be filled will be discussed in co-operation with the SDO that defined these interfaces within Phase 1 and beyond.

Note that during the initial phase, ISG ENI will NOT specify or standardize any interfaces.

Phase 2 (informative/normative): Lasting approximately 12 months from completion of Phase 1, Phase 2 will document the ENI architecture in informative Group Report(s), and demonstrate how the different scenarios defined in Phase 1 are addressed using a dynamic policy-driven management approach. The architecture may be in one document or logically split between documents as required.

The architecture should support the functionality to be able to learn from inputs and decisions, along with information relating to the context of the decisions. This is expected to increase the understanding of both network operation and overall operator goals.

In Phase 2 the output is expected to be a number of informative Group Reports and/or normative Group Specifications.

Phase 3 (informative/normative): Lasting approximately 12 months from completion of Phase 2, Phase 3 would seek to quantify the measurable parameters, and may include interface specification testing and validation if deemed necessary by the group. In particular, the following tasks will be performed in Phase 3:

- quantify the measurement of metrics for equipment, to assure choice when planning, to assure the delivery of different services that meet the requirements for improving operator experience, to understand the impact of how policy-driven functionality is used,

- describe how the ability to measure equipment will improve the equipment available to give better operator experience,
- illustrate the closed-control operation of networks to provide and protect a given level of operator experience.

In Phase 3 or beyond, the ISG ENI may consider the option to develop formal interface specifications, but only where there is a clear need to do so, and if these interfaces are not being developed by other SDOs. The ISG ENI may consider developing both:

- the interface specifications,
- and the associated test specifications.

The output of Phase 3 is expected to be a number of informative Group Reports and/or normative Group Specifications.

6.2 Relation to existing work

Where any overlaps are identified, these gaps will be filled by the existing organization that owns the specification work. There is no overlap as ISG ENI is expected to observe and assist offering automation to the existing network. ENI will describe and specify use cases, requirements, & architecture. Also, a new functional entity that we call an intelligent network engine will assist the process of management and orchestration. This new functional entity is not doing management/configuration or orchestration but is assisting and improving these processes. It may have interfaces into the Network, NFV & MANO, the SDN Controller, through existing APIs and interface specifications, but it is not expected to modify these.

The following Figure 8, Figure 9 andFigure 10 are intended to show that ENI interacts through existing systems as an external entity.

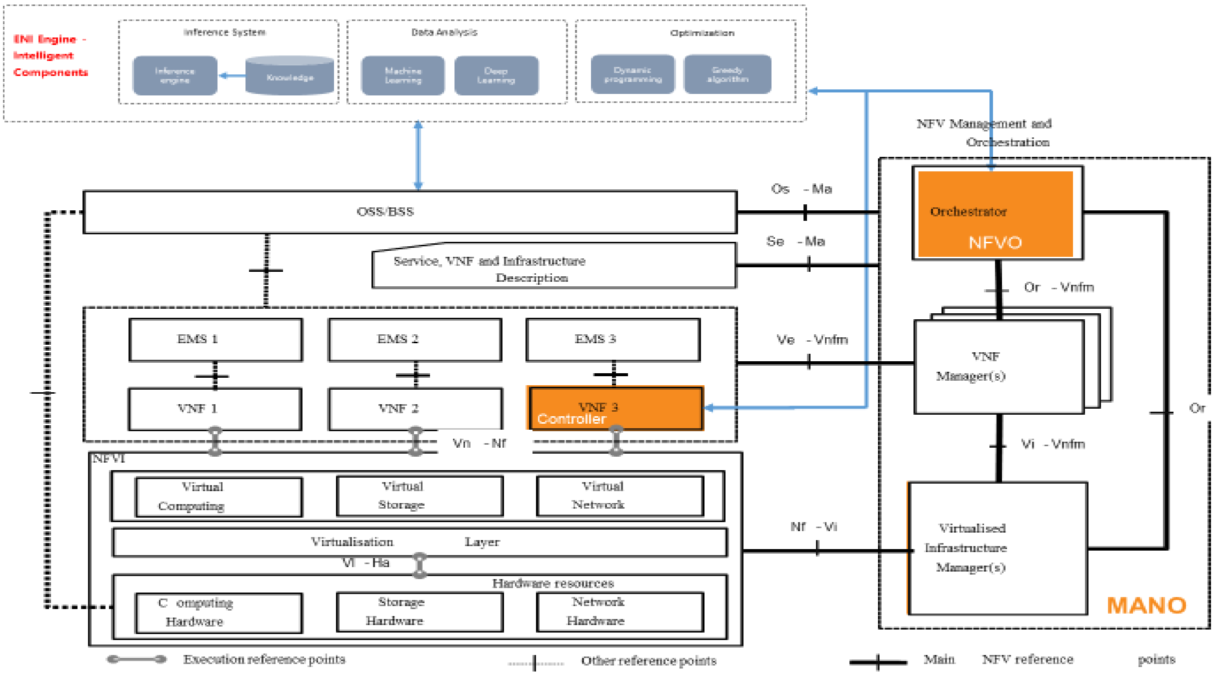

Figure 8: Interaction with NFV and MANO

The Network Big Data Analysis module of the ENI Engine collects the information of MANO's resource description and dynamic resources to include complete meta-data and data for lifecycle management of the virtual environment. The output of the Network Big Data Analysis module can be used to act on the service / policy / resource (consistent with MANO), as well as engineering rules, recipes for various actions, policies and processes.

There is no closed control loop in MANO. The ENI Engine is outside of the MANO elements. This addresses compatibility and avoids rebuilding MANO components.

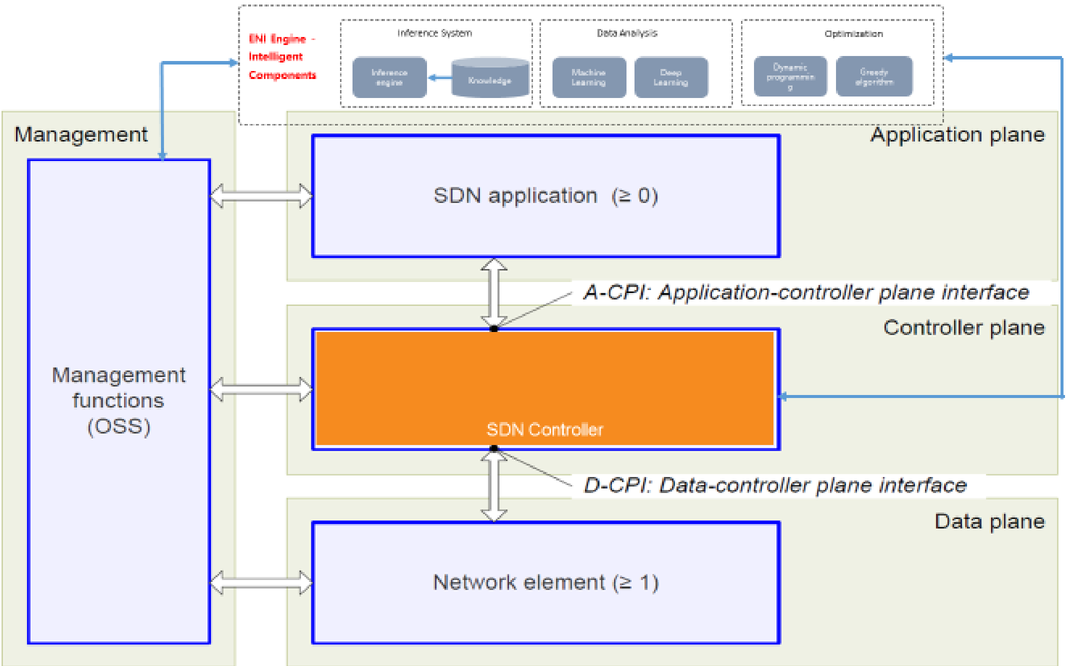

Figure 9: Interaction with the SDN Controller

In SDN, the Network Big Data Analysis module of ENI Engine collects the information both from the SDN data plane and the SDN control plane. The resulting analysis of Network Big Data Analysis helps the service/policy resolver adjust the network / infrastructure.

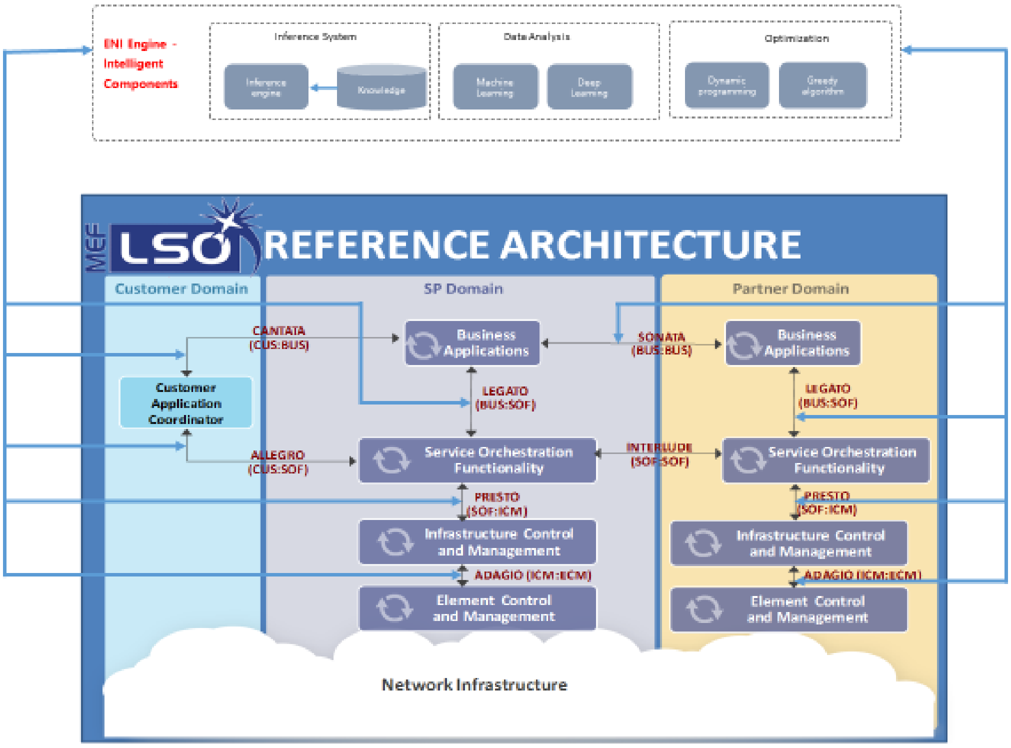

Figure 10: Interaction with MEF LSO RA

The MEF's LSO Reference Architecture defines a set of Management Interface Reference Points that specify the logical points of interaction between different functional management entities. Each Management IRP is defined by an Interface Profile, supported by an information model and a set of data models, and implemented by APIs.

The ENI Engine sits outside the MEF LSO RA functional elements, and augments their behaviour. The ENI Engine interacts with the functional blocks of the LSO RA via the existing APIs defined by the LSO RA; this avoids altering the architecture.

6.3 Benefits of ENI (having an ENI engine)

An ENI engine delivers enhanced operator experience by allowing operators to perceive the operating status of their network and reconfigure their network in real-time. It helps to increase the value of the network to operators by rapidly on-boarding new services, enabling the creation of a new ecosystem of cloud-based consumer and enterprise services, reducing capital and operational expenditures and providing operational efficiencies.

After collecting network status/events, indicators and measures automatically, an ENI engine uses artificial intelligence algorithms to display network performance and quality of service visually, find service bottlenecks or network failure. Then an appropriate policy is generated to adjust the network, services, and capacity accordingly.

Annex: Analysis of work in other SDOs

A.1 Overview

The following contains a brief analysis of known standards bodies that work in the areas of policy management, resource management and service management. None of these SDOs has a model-driven, policy-based, management framework that defines how operator experience may be measured.

It may be seen that none of these SDOs has a policy management framework that defines how policy is used to orchestrate services and resources. The lack of such a framework means that a scalable and consistent mechanism for defining control and management changes does not exist.

In addition, no SDO explains how policy is used in orchestration (except for GANA and the MEF, which both use the concepts taken from FOCALE and DEN-ng). Currently, the MEF appears to have the best orchestration project among the SDOs: they have the latest policy work, a novel, multi-level, distributed orchestration approach, and are taking the best of the TMF and ONF models, pruning, refactoring and extending. The ONF is good for SDN, but does not have business or experience concepts, see Figure 10 for an outline description of SDN as specified on ONF. The ISG ENI may reuse the basis of MEF and try to align the SDOs. The TMF SID is good for business concepts, but its resource and service models need updating. The unique value of ENI is to build on what the MEF is trying to do: enable business needs to drive services and resources delivered on a contextual, personalized basis using a policy-based, model-driven architecture.

For example, the IETF SUPA WG is working on a powerful policy model. The ONF is working on SDN 2.0 defining the Northbound Interface (NBI) to network applications, ETSI NFV is working on the definition and deployment of NFV and its management. TMF has expertise in legacy networks and 3GPP has expertise in the mobile network. The IETF and BBF have expertise in the deployment of Wi-Fi networks.

Work has been undertaken in many SDOs, usually based on specific network environments, as illustrated in Table A-1 (Policy-Service-Resource Management in various SDOs) below. This mode of working often creates a disparate array of ideas that cannot work well together, primarily due to the lack of common abstractions that overcome differences between standards. Whilst many of these ideas have commonalities and shared objectives, a lack of cohesion and co-operation creates barriers to automation and interoperability.

The table below shows “current work” and “work in progress” for these and other relevant SDO efforts related to the scope of the ISG ENI.

Current published work	IETF	IETF NFVRG	IETF ANIMA	ONF	MEF	TMF	ETSI NFV	NTECH AFI	3GPP
Policy	SUPA	No	No	No	XXX (New policy project extending SUPA)	No (work became part of SUPA)	IFA (starting to definition of policy)	GANA working on an older version of what became SUPA	PCC framework
Service	L3SM I2NSF	No	No	No	Service Management in LSO RA	SID, ZOOM (note that ZOOM modelling has stopped	No	No	Flexible Mobile Service Steering (FMSS)
Resource	No	XX	No	SBI	Resource Management in LSO RA	SID, ZOOM (note that ZOOM modelling has stopped)	IFA	Reusing existing work	No

Draft Work in progress	IETF SUPA	IRTF NFVRG	IRTF SDNRG	IETF ANIMA	ONF	MEF	TMF	ETSI NFV	NTECH AFI	3GPP
Business						XX	XX			
Networking	XX	X	X		XXX	XXX	X	XX	X	XXX
Policy	XX	X				X (XXX)		X		XX
Control	XX	X	X	X	X	X (XXX)		XX	X	XXX
Management	X		X	X		X (XXX)			X	XXX
Orchestration				X		XXX		X		XXX

Legend:
X Some work in progress that is relevant
XX Documents that are relevant
XXX Project underway
(XXX) Plans for relevant future work (large project)
(XX) Plans for relevant future work

Table A-1: Policy-Service-Resources Management in various SDO

Today, the work in many standards bodies and open source consortia uses concepts of service and resource. Some of these also use the concept of policy. However, only two SDOs, TMF and MEF, have a detailed information model that describes how policy can be used to manage services and resources. More importantly, the MEF is working on data models and interfaces to realize this as model-driven orchestration systems. However, no single SDO currently defines how to use these concepts to measure or improve the operator experience.

More importantly, many SDOs and open source consortia describe orchestration, but none currently has a detailed model-driven architecture that shows how operators can apply standards to automate their business processes. The advantage of model-driven orchestration is that it enables new behaviour to be defined at runtime without having to reconfigure the data description, recompile, redeploy or stop databases. ENI is built on the premise that the business must be able to dynamically program the infrastructure to deliver resources and services that dynamically adapt to changing user needs, business goals and environmental conditions. Furthermore, this must be done without burdening the operator, and transparently to the end-user. Hence, an ENI engine that performs this model-driven orchestration, using policy management, needs to be studied.

A.2 Definitions & scope of known work in the area

A.2.1 TM Forum

The TM Forum, see www.tmforum.org, has a Business Process Framework (eTOM) and an Information Framework (SID). They don't always integrate well. However, there is a lot of material available that could be incorporated into a part of standardization. For example, this SDO has the best definitions of things like KPIs (Key Performance Indicators), KQIs (Key Quality Indicators), SLAs (Service Level Agreements), and SLSs (Service Level Scripts). In the SID set of specifications, the customer domain is complex but has usefulness - the MEF is currently filtering the customer domain for its own use. The TMF has three information models: SID, ZOOM, and TR225 (TR225 was the basis for the ONF Core resource model); it also has a separate data model used for its API work that is different from each of the information models. We need to analyse where these models are useful within the work on closed-loop context-aware policy-modelling. The TMF has done work on policy, which needs updating, and which does not integrate into the new work developed in the other bodies. TMF has a set of APIs; however, they need modification (e.g., they have no support for the HATEOAS - Hypermedia as the Engine of Application State - principle of REST API design), and are too generic to be used as is. The TMF is also pruning, refactoring, and extending the MEF Modeling APIs. These will be proposed back to the ONF and the TMF.

Furthermore, Joint Agile Delivery is being specified in the TMF in the following documentation: Framework Exploratory Report: "Joint Agile Delivery: Accelerating Value to the End User in a Value Fabric." Release 16.5.1, November 2016 https://www.tmforum.org/resources/exploratory-report/ig1137a-joint-agile-delivery-accelerating-value-to-the-end-user-in-a-value-fabric-r16-5-1/.

A.2.2 ONF

The ONF resource model is geared for networking. It is currently the best, but also the most complex, of the resource models that are being considered. The MEF is pruning and refactoring the ONF core model to both simplify it and to connect the resource model to services and products (among other entities). The ONF does not have many assets in business or policy; its control is oriented toward SDN. It currently has little defined in business or policy management or orchestration.

A.2.3 MEF

The MEF is using a "pruning and refactoring" approach on the SID and the ONF core model to create a unified model that contains business, service and resource components. It is also fixing problems encountered (e.g., the TMF specification pattern and catalog are not useable as is). It also does more active development in YANG than the other SDOs. YANG is a data modeling language used to model configuration and state data manipulated by the NETCONF protocol (RFC 6241), NETCONF remote procedure calls, and NETCONF notifications. The YANG language was developed by the IETF NETCONF Data Modeling Language Working Group (NETMOD), and is defined in RFC 7950, https://tools.ietf.org/html/.

A.2.4 IETF SUPA activities

The SUPA (Simplified Use of Policy Abstractions) working group defines a data model, to be used to represent high-level, possibly network-wide policies, which can be input to a network management function (within a controller, an orchestrator, or a network element). Processing that input most probably results in network configuration changes. SUPA however does not deal with the definition of the specific network configuration changes but with how the configuration changes are applied (e.g. who is allowed to set policies, when and how the policies are activated, changed or de-activated).

List of work items of SUPA WG:

1. An explanation of the scope of the policy-based management framework and how it relates to existing work of the IETF.
2. If the working group considers it necessary, a generic information model composed of policy concepts and vocabulary.
3. A set of YANG data models consisting of a base policy model for representing policy management concepts independent of the type or structure of a policy, plus an extension for defining policy rules according to the event-condition-action paradigm.
4. An applicability document providing a few examples that demonstrate how the YANG policy data models can be used to express policies that are relevant for network operators. The examples may tie into configuration models or network service models developed by other working groups.

This WG is an ongoing work.

A.2.5 IETF L3SM activities

The Layer Three Virtual Private Network Service Model (L3SM) working group was a short-lived WG tasked to create a YANG data model that describes a L3VPN service (a L3VPN service model) that can be used for communication between customers and network operators, and to provide input to automated control and configuration applications.

This WG is concluded.

A.2.6 Open Network Automation Platform: ONAP activities and ONOS

ONAP is an open source project working on real-time, policy-driven orchestration and automation of physical and virtual network functions. See: Open Network Automation Platform: ONAP https://www.onap.org/

Open Network Operating System (ONOS) is an open source SDN network operating system designed for building next-generation SDN/NFV solutions. See: Open Network Operating System (ONOS) http://onosproject.org/.

ENI is a standardization activity, starting with analysis & requirements gathering. Some of ENI's future deliverables can be use cases and requirements to ONAP and ONOS. ENI could be a separate module and interact with the modules already defined in ONAP, e.g. service design & creation, policy creation, AAI, DCAE, MSO, Controllers, to provide intelligent service and policy creation, intelligent analysis, and intelligent service/resource orchestration. This assumes the timescales of ONAP & ONOS can be aligned for input; their timescales are to develop their current initial release.

A.2.7 ETSI NFV

ETSI's Industry Specification Group on Network Functions Virtualisation (ISG NFV) has developed a report on Policy Management in MANO, ETSI GR NFV-IFA 023.

ETSI GR NFV IFA 023 focuses on policy management applied only in the NFV environment, – e.g. VNF resource management and orchestration. We could expect that a future version of GR NFV IFA 023, or another IFA specification, will specify an information model for policy management suitable for orchestrating services and resources to achieve operator experience metrics defined in the ISG ENI. Moreover, the ISG ENI could reuse (and perhaps improve) such an information model coming from other SDOs outside of ETSI through an appropriate liaison within ETSI, from e.g., ETSI ISG NFV.

A.2.8 ETSI NTECH AFI

ETSI's Technical Committee on Network Technologies (TC NTECH) has a working group dealing with Evolution of Management towards Autonomic Future Internet (AFI). They have developed the Generic Autonomic Network Architecture, the subject of an ETSI White Paper on GANA.

NTECH AFI focuses mainly on autonomic networking, which include self-manageability and properties (within network nodes/functions and "in-network" self-management), autonomic management and control (AMC) of networks and services by autonomics introduced in the outer (logically centralized) management and control planes of network architectures. The ETSI AFI GANA Reference Model combines perspectives on these aspects to capture the holistic picture of autonomic networking, cognitive networking and self-management design and operational principles. NTECH AFI performs GANA instantiations onto evolving and future network architectures and their management & control architectures of the future internet. Moreover, NTECH AFI is addressing OPEX challenges faced by network and service providers by measuring the benefit of Autonomics/Self-Management. In contrast, the ISG ENI is focused on improving the experience of the operator in managing any type of network. Since these are different, but complementary, goals, it is envisioned that NTECH AFI could reuse some of the results derived in the ISG ENI (e.g., the information model for policy management and its orchestration approach), as well cooperate on topics related to operator experience and improving OPEX.

A.2.9 IETF NFVRG

https://datatracker.ietf.org/rg/nfvrg/about/ and https://datatracker.ietf.org/doc/draft-irtf-nfvrg-nfv-policy-arch/ - Policy Architecture and Framework for NFV Infrastructures

The IETF NFVRG focuses on two near-term areas that are complementary to the work of the ISG ENI. The first, policy-based resource management, is focused on using policy management to optimize resource allocation and utilization for NFV deployments. These constraints arise from operational considerations within and between data-center networks; hence it is envisioned to address capacity management, energy utilization, green IT, and related operations. The second, analytics, is focused on using real-time analytics to gain increased visibility into performance and resource management. Note, however, that detailed policy models and user's stories have not yet been provided. The ISG ENI is focused on the operator experience and hence can cooperate with work of the NFVRG. For example, ENI will focus on policies for asset lifecycle management, availability optimization, service and resource lifecycle orchestration, and simplifying the operational processes involved in realizing an agile infrastructure. Similarly, the ISG ENI will incorporate analytics (both real-time and non-real-time) as part of the orchestration control loop. This enables the ISG ENI to reuse work from the NFVRG as well as contribute new work on how analytics can help drive the specification of orchestration.

A.2.10 IETF ANIMA

https://datatracker.ietf.org/wg/anima/documents/

IETF ANIMA is focused on building a basic infrastructure that will translate operator intent into a system that behaves autonomically. This first phase is making a number of simplifying assumptions to achieve these goals, though its control plane, bootstrapping process, protocols, and other elements should be reusable by other efforts in the future. This effort is complementary to the ISG ENI. The concept of "intelligent actions" may be implemented through autonomic systems. However, the ISG ENI will concentrate on additional important elements that fulfil the experiential aspects of this vision (e.g., AI mechanisms to learn from deployments and build a more powerful knowledge base, more robust information sharing and analysis, and the incorporation of Big Data mechanisms). Hence, we envision that the ISG ENI and ANIMA will benefit from each other.

A.2.11 ETSI ISG MEC (Multi-access Edge Computing)

MEC provides IT and cloud-computing capabilities within the access network near network subscribers. MEC provides computing/storage/communication resources. MEC faces the scenario of mobile network edge virtualization. It is creating a standardized, open environment to address the problem of third-party application integration on MEC platform; accelerate the mobile edge application development.

ISG ENI and ISG MEC are for different scenarios. However, the problem of very high CAPEX and OPEX for network management, which ENI addresses, also exists under MEC scenarios. So, some of the definitions and specifications of ENI may be reused by MEC.

A.3 Policy Comparison

The TMF has a policy model (based on DEN-ng), that became SUPA, but is now outdated. The big difference is that SUPA updated the TMF model and kept key abstractions but removed declarative policies. Note that the MEF has now taken the SUPA model defined in IETF and they are adding declarative policies into it. The MEF also has a new project that is extending the MEF Lifecycle Service Orchestration (LSO) architecture to include policy-based management.

A.4 Management Comparison

The TMF doesn't have a management model. Instead, they have pieces of models ("fragments") that are not integrated. The MEF lacks a management model. The TMF Orchestration Area is working to enhance the LSO architecture to include detailed policy-based management as part of its orchestration.

A.5 Orchestration Comparison

Orchestration does not exist in the TMF and ONF. The MEF has currently the best vision for orchestration.

A.6 Service Model Comparison

The ONF has not worked on service models. The TMF has a complex Service Model, which lacks details. However, it does connect Service to both the Resource and the Business domains. The MEF is building a new Service model, based on elements of the TMF model, that is tightly linked to both the business and the resource domains and can be used by the LSO architecture. Note that the integration of business to Service, and Service to Resource, is not handled well by any SDO.

A.7 Resource Model Comparison

The TMF has four resource models (SID, ZOOM, TR225, and a separate API data model). This is confusing. The ONF appears to have the better networking resource model; however, that model does not currently reflect computing and storage. The MEF is taking the best of the SID, ZOOM, and ONF Core, and pruning and refactoring and fixing.

A.8 Conclusions regarding operator experience

- No SDO is doing anything on operator experience;
- The MEF LSO is a great starting place, but the place where operator experience would be addressed is in the SOF;
- The work in MEF LSO is currently under development; Currently, there are no plans or proposals to address operator experience in it;
- SUPA has nothing to do with operator experience.

A.9 Conclusions regarding policy

- Most SDOs do not have a policy information or data model. The only three that are known of that do are the IETF, TMF, and the MEF.
- Of these, the TMF model is focused on traditional NMF manual networks.
- The IETF SUPA model is a great model. However, it only models imperative policies. Everyone wants "intent", but intent is the exact opposite of imperative (i.e., intent is declarative).
- The MEF PDO (Policy-driven Orchestration) project will start with the latest version of SUPA, and then add in declarative (and possibly other types of) policies. However, there is a second important difference: the MEF PDO will relate policies explicitly to its orchestration architecture. The IETF SUPA model is not related to any existing architecture.
- In addition, most SDOs do not have an orchestration architecture specified at this level of detail, and those that do (NFV, ONF), do not have a policy model.

As such, none of the SDOs has a mechanism for improving operator experience.

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