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ETSI GANA as Multi-Layer Artificial Intelligence (AI) Framework for Implementing AI Models for Autonomic Management & Control (AMC) of Networks and Services; and Intent-Based Networking (IBN) via GANA Knowledge Planes (KPs)

Towards a "Market Place" for GANA Cognitive Decision-making Elements (DEs) as Procurable and Deployable AI Models (powered by Algorithms for Machine Learning (ML), Deep Learning (DL), Computational Intelligence, etc.) for realizing the AMC Paradigm

GANA = **G**eneric **A**utonomic **N**etwork **A**rchitecture

***White Paper No.4** of the ETSI PoC (Proof-Of-Concept) on 5G Network Slices Creation, Autonomic & Cognitive Management and E2E Orchestration; with Closed-Loop(Autonomic) Service Assurance of Network Slices; using the Smart Insurance IoT Use Case*

Edited by ETSI 5G PoC Consortium Steering Committee and Contributors

ETSI TC INT AFI WG 5G POC

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Related Complementary White Papers:

- ***White Paper No.1:*** *C-SON Evolution for 5G, Hybrid SON Mappings to the ETSI GANA Model, and achieving E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices by Cross-Domain Federated GANA Knowledge Planes*
- ***White Paper No.2:*** *ONAP Mappings to the ETSI GANA Model; Using ONAP Components to Implement GANA Knowledge Planes and Advancing ONAP for Implementing ETSI GANA Standard's Requirements; and C-SON – ONAP Architecture*

- ***White Paper No.3:*** *Programmable Traffic Monitoring Fabrics that enable On-Demand Monitoring and Feeding of Knowledge into the ETSI GANA Knowledge Plane for Autonomic Service Assurance of 5G Network Slices; and Orchestrated Service Monitoring in NFV/Clouds*

- ***White Paper No.5:*** *Artificial Intelligence (AI) in Test Systems, Testing AI Models and the ETSI GANA Model's Cognitive Decision Elements (DEs) via a Generic Test Framework for Testing ETSI GANA Multi-Layer Autonomics & their AI Algorithms for Closed-Loop Network Automation*

Executive Summary

ETSI has recently published the Generic Autonomic Networking Architecture (GANA) Standard (ETSI TS 103 195-2), an Architectural Reference Model for Autonomic Networking, Cognitive Networking and Self-Management of Networks and Services in which Artificial Intelligence (AI) plays a role in autonomic management and control of networks and services [2]. The ETSI GANA Standardized Framework defines the paradigm called Autonomic Management and Control (AMC) of Networks and Services. The AMC paradigm (closed-loop service instantiations and adaptive operations) is now being introduced into network architectures and their associated management and control architectures, especially considering the increasing maturity of AI algorithms that are applicable for AMC. ETSI TC INT AFI WG is producing instantiations of the GANA model onto various network architectures and their associated management and control architectures (e.g. GANA instantiation onto BBF architecture scenarios (ETSI TR 103 473 V1.1.2) and GANA instantiation onto the 3GPP Backhaul and Core Network architectures (ETSI TR 103 404)), thereby enabling innovators and developers to implement AMC algorithms and software for diverse target network environments. AMC paradigm is a requirement for IMT-2020 Networks, and ITU-T Y.3324 Recommendation on Requirements and Architectural Framework for Autonomic Management and Control of IMT-2020 Networks adopts the ETSI GANA Model and recommends a use case to realize AMC in IMT-2020 through ETSI GANA reference model. ETSI TS 103 195-2 defines an Intelligent Management and Control Functional Block called GANA Knowledge Plane (KP) that is an integral part of Management and Control Systems for the network and provides for the space to implement complex network analytics functions that must be performed by interworking Modules for decision-making and closed-loop execution of network management and control operations called GANA Decision Elements(DEs).
The KP DEs run as software in the Knowledge Plane Platform and drive *self-* operations for AMC such as self-adaptation, self-optimization, self-monitoring, self-protection and self-defense* objectives for the network and services by programmatically (re)-configuring Managed Entities (MEs) such as protocols and other configurable network resources and parameters of the network infrastructure through various applicable means e.g. through the NorthBound Interfaces available at the OSS (Operations Support Systems), Service Orchestrator, Domain Orchestrator, SDN (Software-Defined Networking) controller, EMS/NMS (Element Management System/Network Management System), NFV (Network Functions Virtualization) Orchestrator and/or MANO (Management and Orchestration) stack in general, etc. ETSI TS 103 195-2 also defines "***Requirements for Protocols and APIs (Application Programming Interfaces) for Enabling GANA based Autonomics, Cognitive Networking and Self-Management of Networks and Services in Evolving and Future Networks***". The GANA AMC paradigm has been adopted as basis for introducing the AMC paradigm in the NGMN 5G End-to-End Architecture [4], in TMForum's ODA (Open Digital Architecture) [6][18] and the Broadband Forum (BBF) architecture scenarios (ETSI TR 103 473 V1.1.2). The Open Source community such as those referenced in [9][10][11][12][13][14][15][16][19] are also embracing the AMC paradigm and are offering components that enable to implement GANA components for AMC such as Knowledge Planes (in reference to [19] for example).

The ETSI 5G PoC (Proof-Of-Concept) on "***5G Network Slices Creation, Autonomic & Cognitive Management and E2E Orchestration; with Closed-Loop(Autonomic) Service Assurance of Network Slices; using the Smart Insurance IoT Use Case***", has the key aim of operationalizing the GANA AMC paradigm in 5G while giving various solution suppliers and other players outlined in ETSI White Paper No.16 the opportunity to showcase AMC solutions that implement specific aspects of the GANA Model, and/or the opportunity to obtain guidance on how solution suppliers can adapt their solutions to the ETSI GANA Standard.

As the industry quest for standards based solutions for AMC (powered by AI) is growing rapidly, this ETSI 5G PoC continues to offer the opportunity to showcase the ETSI GANA as Multi-Layer Artificial Intelligence (AI) Framework for Implementing AI Models for Autonomic Management & Control (AMC) of Networks and Services. Therefore, this paper covers this subject as well as the subject of Intent-Based Networking (IBN) using the concept of GANA Knowledge Planes, and provides guidance to the industry towards introducing the new concept of a Market Place for GANA Cognitive DEs as AI Models for AMC as one step of the whole GANA DE life cycle that involves DevOps and AIOps (AI-driven Operations).

NOTE: Readers are encouraged to download and read the more detailed *White Papers and Slides from Demos* of the ETSI 5G PoC available at [3]: https://intwiki.etsi.org/index.php?title=Accepted_PoC_proposals .

1. "A~ted~A~mic~A~mous" ("3As"): Automated Management vs Autonomic Management vs Autonomous Network Behaviour: Taxonomy Harmonization

1.1. Background on the Terminology and related Industry Standards

There are terminological terms that are related to the broad concept of ***Network Automation*** that have been confusing the industry in getting the correct interpretation of the terms, as the network automation aspects associated with the terms are rather complementarily intertwined and there has not been a model that clearly defines the relationships of the concepts associated with the terms. This section provides a harmonization of the terminologies on Network Automation and presents the terminology harmonization model that captures the relationships among the concepts behind the terms, to help the industry to interpret the concepts precisely without ambiguities, and understand the complementarities of the terms starting with basic background and progress the industry has made in Network Automation:

- A System that operates using Control-Loop(s) is a called an **Autonomic System**, and so the system property of exhibiting a closed-loop (or control-loop(s)) is called **Autonomicity** (as of standards in ETSI (e.g. ETSI TS 103 195-2) and other literature), and the *science of control-loops* is called *autonomics*
- There are Standards that have now been established on Autonomic Networks and Principles by which to design and operate them (e.g. ETSI GANA Model (ETSI TS 103 195-2) and GANA autonomics instantiations onto various architectures such as BroadBand Forum (BBF) architectures (ETSI TR 103 473 V1.1.2); 3GPP Backhaul and Core Network (ETSI TR 103 404)) and ITU-T Y.3324. Autonomics (Closed Control-Loops) is already being embedded in Network Elements/Functions (NEs/NFs) of Network Infrastructures and in Management and Control Architectures for Networks (e.g. SON (Self-Organizing Networks) for RAN, and in the case of AI powered Management and Control Systems in general).
- An Autonomic Network is one that continuously senses its "Environment", and in a closed-loop manner (autonomic), proactively and reactively adapts to changes in the "Environment" so as to strive to achieve target goals or to maximize a certain utility. The "Environment" includes the Interfaces with other networks, various data sources, and the so-called Governance Interface through which a Human Operator provides inputs to the Autonomic Network such as Business Objectives, Goals, Policies and Intents. The concept of autonomicity can be applied to entities of varying scale and associated "environments": hence *autonomic component; autonomic node, autonomic system, etc*. Self-* attributes of a system such as *Auto-Discovery*, *Self-Configuration, Self-Diagnosis, Self-Repair, Self-Optimization, Self-Protection, Self-Healing, Self-Aware, etc.*, are associated with autonomic systems (see definitions in ETSI TS 103 195-2).
- An Autonomic Network either refers to the Network Infrastructure made up of Network Elements/Functions (NEs/NFs) that exhibit autonomics in their behaviors, or is the inclusion together of Network Infrastructure with some level of autonomics in NEs/NFs and its associated Management and Control architecture that also exhibits autonomics (control-loops) at that higher level
- Studies in Research and by ETSI TC INT/AFI WG regarding a property of system of being "**Autonomous"** have built an understanding that the industry is often confused by the term "Autonomous" as "Autonomous Systems" often imply Self-Governance (i.e. totally removing the human from the loop such that the system takes decisions without human influence by governance during its lifetime). Fully autonomous systems (i.e. self-governing) systems may be designed and deployed in environments where human interaction is not expected in their operations (e.g. robots deployed on Mars Planet, or robots meant to be deployed in environments not accessible by humans), but Business oriented Telecommunication Networks, while they need to become "**Autonomic**" in their Operations and also exhibit a certain level of "**Autonomy**" or being "**Autonomous**" from the perspective of certain operations that can be performed by the network without direct human involvement in the decision and actions, shall always need to be Governed by Human Operator

Inputs, and hence should never be considered as fully autonomous at any stage like in the case of fully Autonomous Vehicles.

- ETSI TC INT /AFI WG (which evolved from the ETSI ISG AFI that was established in 2009) has established that Telecommunications Networks (including IP and IT Networks), as they become Autonomic Networks, will still always have to be governable by the Human Operator through Inputs such as Business Objectives, Goals, Policies and Intents, and hence they shall never be self-governing (except for some kind of ad-hoc networks like tactical networks deployed in battlefields).

1.2. Establishing the Relationships between the Terms and Associated Concepts

The Relationship between Autonomic Management & Control (AMC) and Automated Management of Networks and Services:

- ***Automated Management*:** It is about **workflow reduction and automation** i.e. **automation of the processes** involved in the creation of network configuration input using specialized task **automation tools (e.g. scripts, network planning tools, policy generators for conflict-free policies)**

- ***Autonomic Management*:** It emphasizes **learning, reasoning, and adaptation** *using control-loops that also take into consideration the feedback knowledge obtained from network and services monitoring*. **Automated Management** provides input to the Autonomic Management & Control (AMC) of Networks and Services Domain ("area"). ETSI White Paper No.16 and ETSI TS 103 195-2 define the AMC paradigm as the interworking of nested and hierarchical control-loops and associated logics introduced in the Management Plane, in the Control Plane, and also in the converged (non-disaggregated) Management Planes and Control Planes (as there are such cases). **Remark**: ***Autonomic Management*** is broadly encompassing the AMC paradigm. Indeed, *Autonomic Management* must exhibit a network governance interface through which the input that governs the configuration of an Autonomic Network should be provided by the human operator. Thanks to automation tools and mechanisms (*Automated Management*), by using a high level language, the operator can define the features of the network services that should be provided by the underlying network infrastructure. Such a business language that can help the operator express high level business goals required of the network may be modelled by the use of an ontology to add semantics and enable machine reasoning on the goals. The human operator defined features relate to business goals, technical goals and some input configuration data that an autonomic network is supposed to use as operational targets (which may flexibly be changed or modified by the operator at any time) for network resources and parameters configurations.

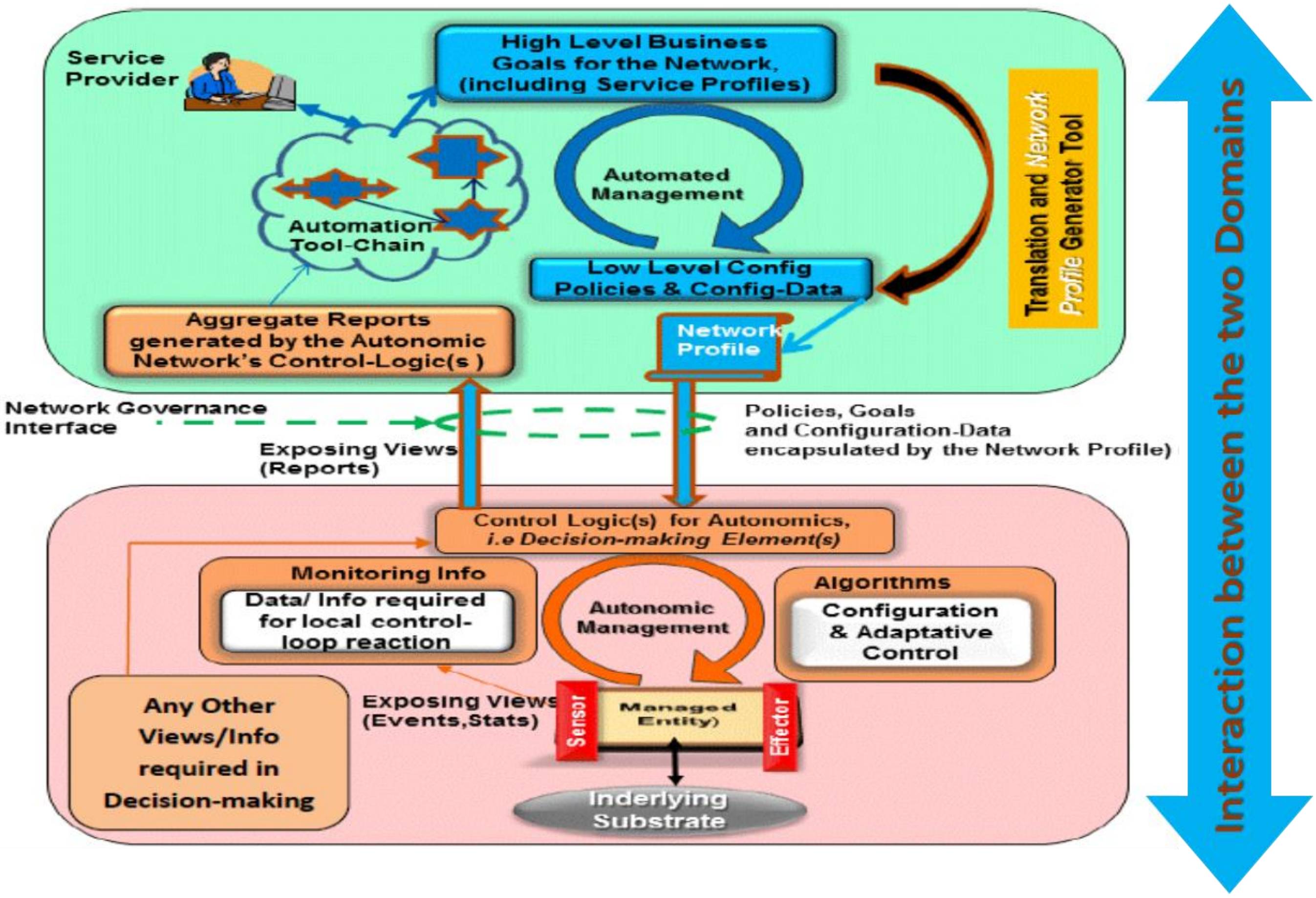

Figure 1: ***The Relationship between Autonomic Management & Control (AMC) depicted as "Autonomic Management" and "Automated Management" of Networks and Services***

Relationships of Network Properties of "*being Autonomic*" and "*being Autonomous*":

- *The Concept of an Autonomic Network is now widely understood and backed by Standards in various SDOs/Fora, such as ETSI, ITU, 3GPP, IEEE, BroadBand Forum(BBF), TMForum, IETF, MEF, and other groups.*

- ***Definition of an Autonomic Network (AN):*** *An Autonomic Network (AN) either refers to the Network Infrastructure made up of Network Elements/Functions (NEs/NFs) that exhibit autonomics (control-loops) in their behaviors, or is the inclusion together of Network Infrastructure with some level of autonomics (control-loops) in NEs/NFs and its associated Management and Control architecture that also exhibits autonomics (Control-Loops) at that higher level*

- The diagram below (Figure 2) provides a model that captures the relationship between the two properties desired of an Autonomic Network (AN), namely that of being "autonomic" and that of being "autonomous". The AN's property of being "*autonomic*" (also called "*autonomicity*" in ETSI Standards such as ETSI TS 103 195-2), relates to **Hierarchical (nested) and Interworking *Control-Loops* introduced at various Abstraction Levels (from NE/NF level) up into the Management & Control Systems Level**. Whereas the AN's property of being "autonomous" refers to the ***Degree and Measure of Operations Tasks that can be performed by the autonomic network (AN) without direct human involvement in the decision and actions***. In the relationship of the two properties, one can realize that the science of Control-Loops (called "*Autonomics*") is key enabler for achieving the property of being autonomous, and that an AN is expected to evolutionarily "maximize" the property of being "autonomous" in as far as the "***Degree and Measure of Operations Tasks that can be performed by the autonomic network (AN) without direct human involvement in the decision and actions***". That means that evolving the Autonomics (Control-Loops) of the AN by enrichment of automation in management, control and associated intelligence, *Maximizes* the AN's property of being Autonomous (but while still remaining governable and controllable by humans—particularly for telecommunication and IT networks meant to serve business customers of network providers). The "evolution" takes different paces in deployed ANs of various organizations. Therefore, ***Evolutionary Autonomic Networks*** are characterized by the ability to **evolve in maximization of the property of being "Autonomous" (degree of Autonomy** in operations tasks**)** by enriched automation using Control-Loops, to reach an extent by which the human operators see themselves focused mainly on providing Governance Inputs (Business Objectives, Goals, Policies and Intents) to the Network while experiencing a drastic reduction of involvement in any burdens involving tasks such as security management/control, fault-management and Network Optimization processes for the network (thanks to autonomics features such as *self-repair, self-healing, self-protection and self-optimization* by the network on its own).

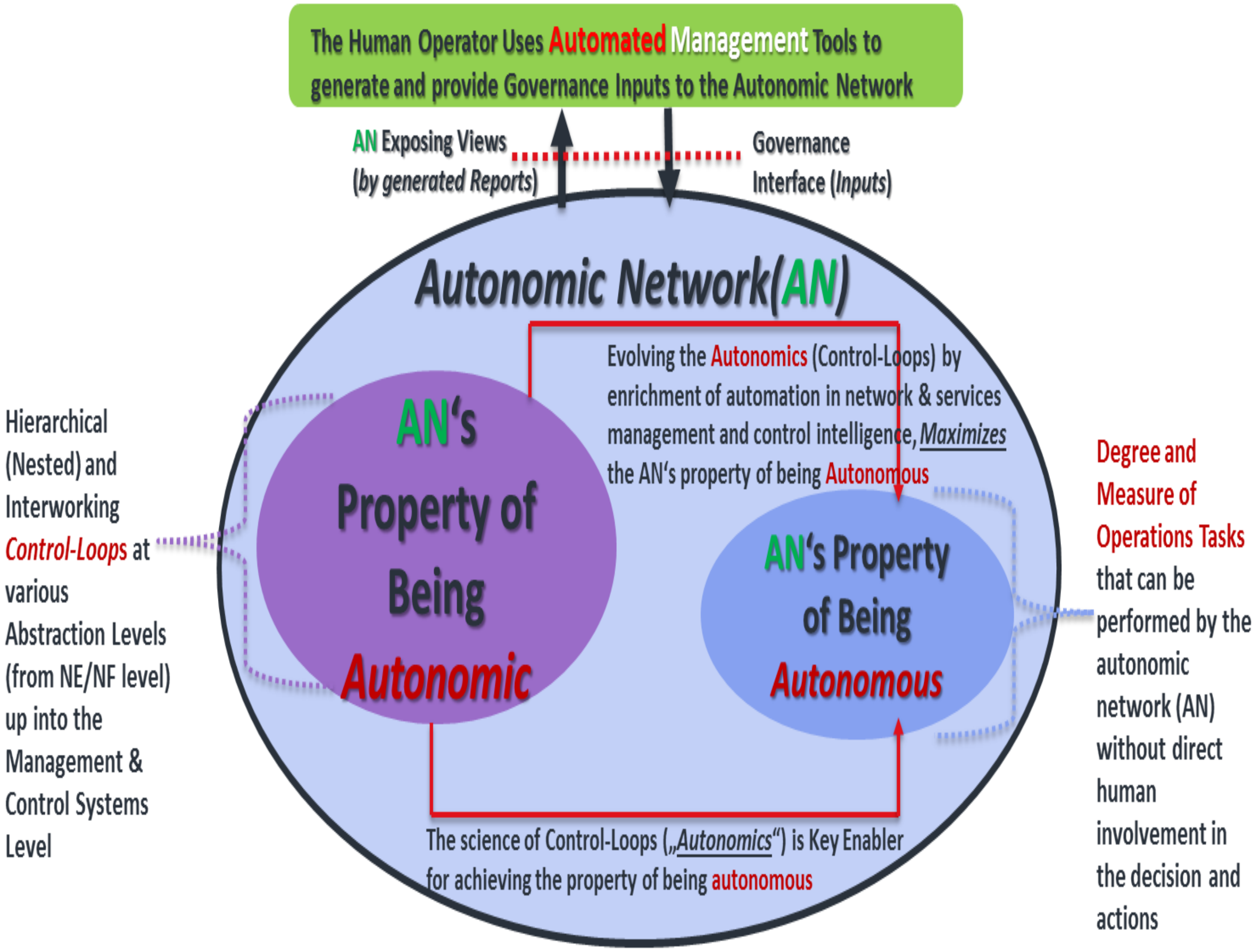

Figure 2: ***Relationships of Network Properties of "being Autonomic" and "being Autonomous"***

On Autonomic Management & Control (AMC) vs Automated Management vs Autonomous network behaviour (the 3As):

- The Figure 3 below provides a consolidated view of ***Autonomic Management & Control (AMC)*** **vs** ***Automated Management*** **vs** ***Autonomous network behaviour*** **(the 3As):**

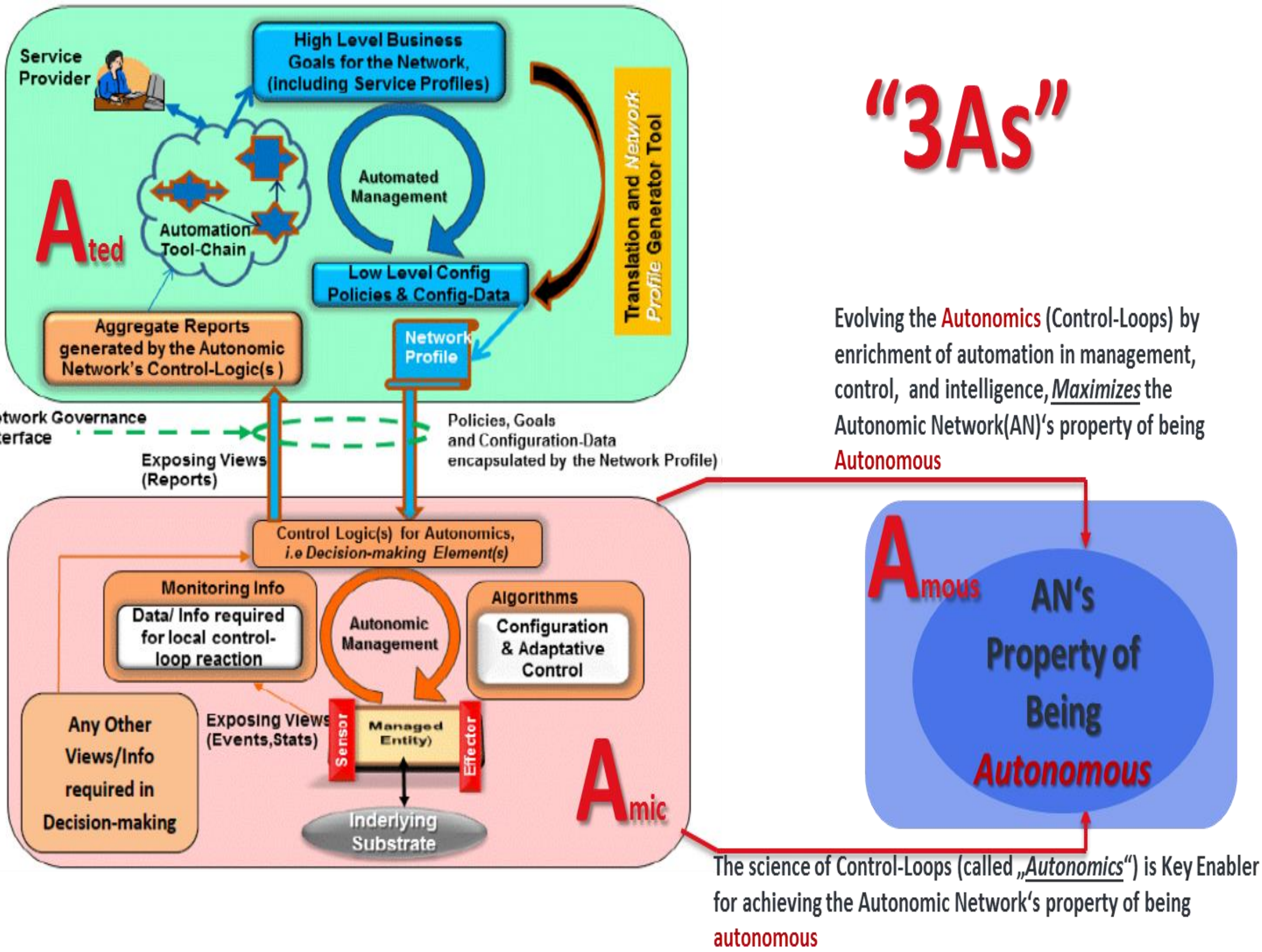

Figure 3: ***Autonomic Management & Control (AMC) vs Automated Management vs Autonomous Network Behaviour ("3As")***

2. ETSI GANA Model as Multi-Layer Artificial Intelligence (AI)/Machine Learning (ML) Reference Model for Autonomic Management & Control (AMC) of Networks and Services

1.1. Overview

The ETSI TS 103 195-2 [2], a standard of a Generic Autonomic Networking Architecture (GANA)—an Architectural Reference Model for Autonomic Networking, Cognitive Networking and Self-Management of Networks and Services, defines the concept of what is called an "**Autonomic Manager** element" (called a "**Decision-making-Element" (DE)** in the GANA terminology) as a functional entity that drives a control-loop meant to configure and adapt (i.e. regulate) the behaviour or state of a Managed Entity (i.e. a resource)—usually multiple Managed Entities(MEs). Figure 1a presents a snapshot of the GANA Framework and the abstraction levels at which DEs for implementing control-loops and the interworking the DEs should be considered in order to implement multi-layer autonomics.

ETSI TC INT AFI WG's work on E2E autonomic networking involves introducing self-manageability (autonomics) properties (*e.g. auto-discovery, self-configuration, self-diagnosis, self-repair, self-healing, self-protection, self-defence, self-awareness, etc*.) within network nodes/functions themselves and also enabling distributed "*in-network*" self-management within the data plane network architectures (and their embedment of "thin control planes"). This low level intelligence (autonomics) achievable by so-called "GANA DEs" that should be instantiated to drive fast control-loops within network nodes/elements and to drive horizontal, self-adaptive, and collaborative "in-network" behaviour involving the collaboration of certain autonomic nodes at certain points in a network topology is also called "*Micro level*" autonomics ("fast control loops"). The low level autonomics shall be complemented and policy-controlled (governed) by higher level autonomics ("slow control loops") (at "*Macro level*"). *Macro level autonomics* is achievable and driven by higher level *"*GANA DEs" responsible for network-wide and logically centralized autonomic management and control of networks and services. At "Macro level", the autonomics paradigm (control loops) is introduced outside of network elements, in the outer, logically centralized, management and control planes architectures of a particular target network. This outer "realm" for implementing the much more complex, cognitive and analytics algorithms (including Artificial Intelligence (AI) Algorithms) for autonomics that operate on network-wide views is called the GANA Knowledge Plane (GANA KP). The three key Functional Blocks of the GANA KP are summarized below (more details are found in the ETSI GANA standard itself (ETSI TS 103 195-2)):

- **GANA Network-Level DEs**: *Decision-making-Elements (DEs)* whose scope of input is network wide in implementing "slower control-loops" that perform policy control of lower level GANA DEs (for fast control-loops) instantiated in network nodes/elements. The Network Level DE are meant to be designed to operate the outer closed control loops on the basis of network wide views or state as input to the DEs' algorithms and logics for autonomic management and control (the "Macro-Level" autonomics). The Network-Level-DEs (Knowledge Plane DEs) can designed to run as a "micro service".
- **ONIX (Overlay Network for Information eXchange)** is a distributed scalable overlay system of federated information servers). The ONIX is useful for enabling auto-discovery of information/resources of an autonomic network via "publish/subscribe/query and find" mechanisms. DEs can make use of ONIX to discover information/context and entities (e.g. other DEs) in the network to enhance their decision making capability. The ONIX itself does not have network management and control decision logic (as DEs are the ones that exhibit decision logic for Autonomic Management & Control (AMC)).
- **MBTS (Model-Based Translation Service)** which is an intermediation layer between the GANA KP DEs and the NEs ((Network Elements)—physical or virtual)) for translating technology specific and/or vendors' specific raw data onto a common data model for use by network level DEs, based on an accepted and shared information/data model. KP DEs can be programmed to communicate commands to NEs and process NE responses in a language that is agnostic to vendor specific management protocols and technology specific management protocols that can be used to manage NEs and also policy-control their embedded "micro-level" autonomics. The MBTS translates DE commands and NE responses to the appropriate data model and communication methods understood on either side. The value the MBTS brings to network programmability is that it enables KP DEs designers to design DEs to talk a language that is agnostic to vendor specific management protocols, technology specific management protocols, and/or vendor specific data-models that can be used to manage and control NEs.

The "GANA" reference model combines perspectives on NE/NF embedded GANA DEs ("Micro-Level" autonomics (defined by the so-called GANA levels-1 to Level-3 illustrated in Figure 1a)) and their interworking with GANA KP DEs (GANA level-4)—i.e. the "Macro-Level" autonomics realized by the GANA Knowledge Plane). The reference model also defines the responsible Functional Blocks and Reference Points that enable developers to implement autonomics software, with all perspectives combined together so as to capture the holistic picture of autonomic networking, cognitive networking and self-management design and operational principles. This ETSI GANA Framework is illustrated in Figure 1a. **NOTE:** The *Four GANA Levels of abstraction of self-management functionality* at which control-loops can be introduced are defined to great detail in ETSI White Paper No.16 [1]and ETSI TS 103 195-2 [2], with arguments as to why the *three GANA Levels 2 to 4* should be the most important levels to consider when introducing autonomics in network architectures.

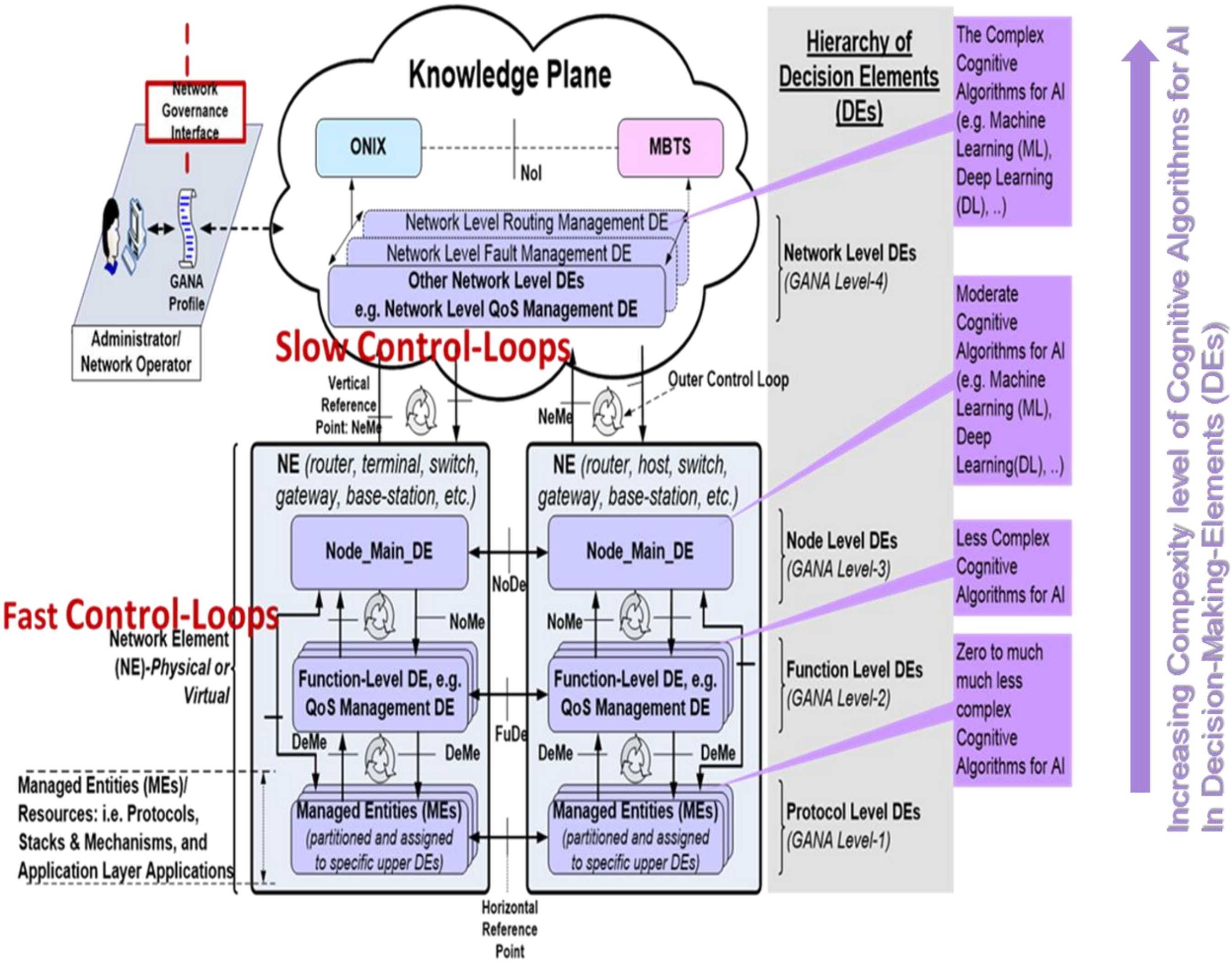

Figure 4a: *Snapshot of the GANA Reference Model and Autonomics Cognitive Algorithms for Artificial Intelligence (AI)*

As such (in reference to Figure 4a) the ETSI GANA Standardized Framework for AMC (ETSI TS 103 195-2) defines an Intelligent Management and Control Functional Block called GANA Knowledge Plane (KP) Platform that is an integral part of Management and Control Systems for the network—as that part that provides for the space to implement complex network analytics functions performed by interworking Modularized and specialized DEs. The KP DEs run as software in the Knowledge Plane and drive *self-* operations for AMC such as self-adaptation, self-optimization, self-monitoring, self-protection, self-defense* objectives for the network and services by programmatically (re)-configuring Managed Entities (MEs) such as protocols and other configurable network resources and parameters of the network infrastructure through various means possible: e.g. through the NorthBound Interfaces available at the OSS (Operations Support Systems), Service Orchestrator, Domain Orchestrator, SDN (Software-Defined Networking) controller, EMS/NMS (Element Management System/Network Management System), NFV (Network Functions Virtualization) Orchestrator and/or MANO (Management and Orchestration) stack in general, etc.

The GANA KP consists of multiple modularized DEs. In contrast to non-modularized management systems, each DE is expected to be a module (as atomic block) and that it should address a very specific "management & control domain (scope of management/control aspects/problems)" such that it can run as a "micro service". Examples of autonomic manager elements (i.e. DEs) are: *QoS-management-DE, Security-management-DE, Mobility-management-DE, Fault-management-DE, Resilience & Survivability-DE, Service & Application management-DE, Forwarding-management-DE, Routing-management-DE, Monitoring-management-DE, Generalized Control Plane management-DE*.

DE components of the GANA KP are "macro" autonomic managers (atomic and modular) that are logically centralized and operate on network-wide views in driving slow control loops that adaptively program and policy-control the behavior of Network Elements/Functions (NEs/NFs) while operating in "slower timescale" than similar control-loops introduced to run in NEs/NFs and operating as "fast control-loops". Macro autonomic managers (GANA KP DEs) should be complemented by "micro" Autonomic Manager components (DEs injected into NEs) that can be introduced in the Network Elements (physical or virtualized) for driving local intelligence within individual network elements to realize "fast control-loops" in network elements. Macro autonomic managers (GANA KP DEs) policy-control the "micro" autonomic managers (GANA DEs in NEs—i.e. the so-called GANA Level-2 and Level-3 in the ETSI TS 103 195-2).

The Figure 4b, depicts the Instantiation of the GANA Multi-Layer AMC Reference Model onto any Network Architecture (an existing or newly standardized one) named "Production Network". Such Network Architectures includes the likes of ITU-T/IMT 2020 Networks, 3GPP (v)EPC, 3GPP 5GCN, 3GPP 5G RAN, BroadBand Forum (BBF) Architecture, NGMN 5G E2E Architecture Framework [4], TMForum ODA Production Architecture Framework [xxx], Cloud architecture, Edge architecture, Data Center architecture, X-Haul Transport architecture, etc.)

Clarifications of the Blue part of Figure 4b

- "Micro-Level" autonomics (defined by the ETSI GANA levels-1 to Level-3 illustrated in Figure 4a))

Clarifications of the Grey part of Figure 4b

- "Macro-Level" autonomics (defined by the ETSI GANA levels-4, illustrated in Figure 4a)). It is realized by the Knowledge Plane that is an integral part of Management and Control Systems of the underlying network.

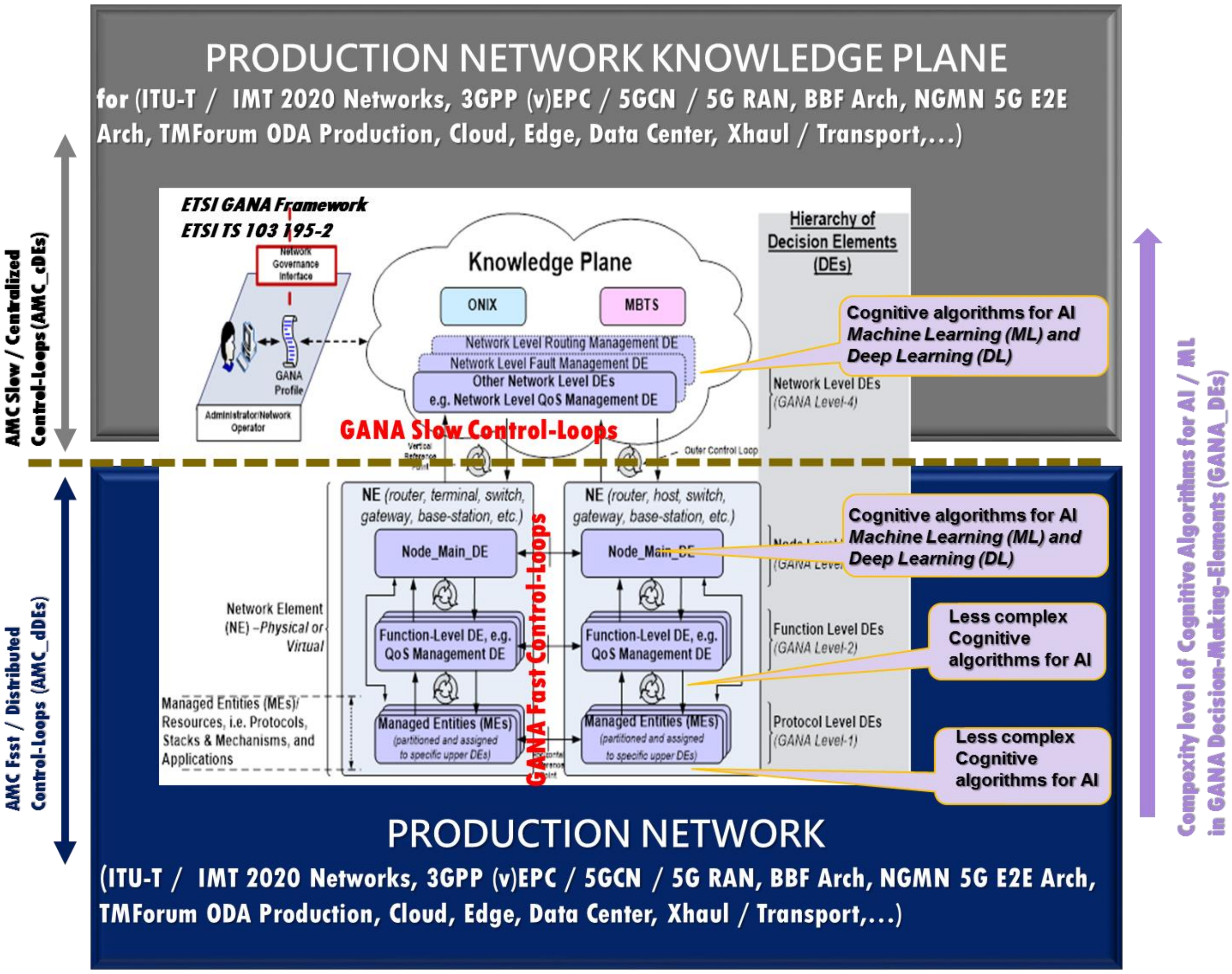

Figure 4b: Instantiation of GANA Multi-Layer AMC Reference Model onto any Architecture (existing or a newly standardized one) named "Production Network"

1.2. Further Characterization of Cognitive DEs as Deployable AI Models for Realization of AMC

As described in more details in ETSI 5G PoC White Papers No.1, No.2 and No.3 (all downloadable from https://ntechwiki.etsi.org/index.php?title=Accepted_PoC_proposals), GANA Decision-making-Elements (DEs) designed as Cognitive DEs (DEs with ability to learn and reason) can be viewed and treated as "AI Models" that can be loaded into Network Functions or into the Knowledge Planes (KPs) Platforms for AMC realization at the specific level in GANA. A cognitive DE can be designed in such a way that it is a "deployable" AI Model, meaning that it can be loaded to run in a system such that it is associated with a run-time instance, and can be activated/deactivated or removed from the system or execution environment.

An Autonomic Management & Control (AMC) component (such as a GANA DE) is a Software Component that is used to implement a Closed-Loop (Control-Loop) over its Managed Entity(ME) (or Entities) to dynamically configure the ME(s) to meet certain objectives, and use AI Algorithms (e.g. ML, DL) to exhibit cognitive behaviour in its operation. ETSI TS 103 195-2 defines "***DE to Managed Entities (ME(s)) association relationships***" for various types of DEs.

GANA instantiations onto various network architectures and their associated management and control architectures (e.g. GANA onto BBF Architecture Scenarios (ETSI TR 103 473 V1.1.2), GANA onto 3GPP Backhaul & Core Network (ETSI TR 103 404), etc.) provide concrete "***mappings of DEs to MEs***", thereby enabling DE innovators to then use such mappings in innovating DE algorithms (including their AI algorithms) and the overall logics. ETSI 5G PoC White Papers No.1, No.2 and No.3 (all downloadable from https://ntechwiki.etsi.org/index.php?title=Accepted_PoC_proposals) also provide illustrations of GANA implementations.

Considering a Cognitive GANA DE as AI Component (AI Model), an AI Model Supplier that is a Supplier of GANA DEs (embedded in NEs/NFs or loadable into NEs/NFs or loadable into the KP overarching Platform) as AI Models for AMC is characterized as follows:

- **The Supplier** may be an Independent Software Vendor (ISV), Network Infrastructure NE/NF Vendor/Supplier, or may be any player that relies on Autonomic Management & Control Domain Expert(s) to produce Cognitive DEs. Each DE of the GANA Knowledge Plane (KP) is expected to be cognitive in its intelligence for AMC, whereby the property of being cognitive is the ability to learn and reason. A Supplier of Cognitive DE modules (components) is one that may have the capability to develop and supply DEs of the GANA Knowledge Plane (KP) as a whole (though each DE of the KP may be designed and implemented and supplied by different implementers/suppliers). Alternatively, or in addition, the supplier of Cognitive DEs is one with the capability to develop and supply Cognitive GANA Levels 2 and 3 that can be injected (loaded) into a Network Element/Function (NE/NF) to enable NE/NF self-management intelligence and enable to realize distributed control-loops involving multiple NEs/NFs of a certain scope that make the NEs/NFs self-organize and self-manage in complementing centralized control-loops driven by the DEs of the GANA Knowledge Plane Platform that covers the NEs/NFs .
- **Packaging of DEs (AI Models):** In general, a non-cognitive DE or a DE that exhibits AI algorithm(s) for Autonomics (i.e. a Cognitive DE), can be supplied under the two following modes: **1)** *"DE for White Box" mode: Meaning that the DE is meant to be injected into an Network Element/Function (NE/NF, i.e. Physical Network Function (PNF) or Virtual Network Function (VNF)) that is built on a white box* ; **2)** *"DE embedded in Black Box NE/NF" mode: Meaning that the DE comes already embedded into NE/NF by NE/NF Manufacturer*;

Implementation flavors of Cognition capability of DEs:

- Regarding **designing Cognitive DE(s), a Cognition Module "CM"** as a Data Analytics Module can be commonly shared by multiple cognitive DEs without having to make a cognitive DE intrinsically embed own cognition module (CM) individually. A Cognition Module implements cognitive algorithms that operate on raw data to synthesize knowledge that can be represented in certain formats and used or communicated to multiple DEs (if it is a commonly shared CM and not a CM embedded in an individual DE) to aid the DE(s)' autonomic operations and decision-making logics' intelligence. Therefore, there are two options that can be taken when designing a cognitive DE, embedding a Cognition Module in a DE individually or having a shared Cognition Module for all DEs within the scope of a NE/NF or within the scope of a GANA Knowledge Plane Platform instance.

How a Centralized Data Collector (Data Lake) interacts with DEs (AI Models)?

- Regarding a **Centralized Data Collector (Data Lake):** A Data Collector may be external to the GANA Knowledge Plane but integrated with the GANA Knowledge Plane Platform in such a way that it feeds the KP with knowledge by streaming knowledge synthesized/derived from the raw data gathered and stored on the collector to the GANA Knowledge Plane. Therefore, a Data Collector (Data Lake) should implement RAT (Representation, Acquisition, Translation) Function defined in ETSI TS 103 195-2 and Cognitive Algorithms that synthesize (derive) knowledge from the raw data and stream the knowledge to Knowledge Plane DEs and ONIX as consumers as described in ETSI TS 103 195-2, as the RAT (Representation, Acquisition and Translation) Function of a Data Lake or Data Collector is also a concept described in ETSI TS 103 195-2. Therefore, Cognitive Algorithms (or Cognition Module) for Data Analytics may be implemented directly on the Data Lake (Data Collector) by implementing the RAT (Representation, Acquisition and Translation) Function.

3. Implementation Approaches for GANA DEs and their associated Control-Loops

ETSI White Paper No.16 (https://www.etsi.org/images/files/etsiwhitepapers/etsi_wp16_gana_ed1_20161011.pdf) [1] and ETSI TS 103 195-2 provide more detailed insights on how to use the GANA framework in implementing AMC through the Slow-Control-Loops by Knowledge Plane levels DEs and Fast Control-Loops by GANA levels 2 & 3 DEs injected into NEs/NFs, and how to interwork the two levels of autonomics. The implementation approaches and aspects that need to be considered when implementing Slow Control-Loops by Knowledge Plane Decision Elements (DEs) and Fast Control-Loops by DEs implemented in Network Elements/Functions are as follows:

a) "Top-Down Approach" to implementing GANA autonomics in networks can be pursued as described in ETSI White Paper No.16, in what has been referred to as a "top down approach" to implementing by taking a phased approach that starts with higher level autonomics by GANA Knowledge Planes and the streaming of Telemetry Data to Common Data Lakes (centralized Data Collectors) and/or to the Knowledge Plane, and making the telemetry consumed by DEs in the Knowledge Plane (KP) for the autonomic operations by the KP. However, such "top-down" and phased approach to implementing GANA autonomics levels could be suitable to some scenarios like the case of legacy network environments (consisting of physical network elements) in which there may be constraints regarding the possibility to introduce local DEs (level 2&3 DEs) in the NEs/NFs. A "Top-Down approach" to implementing and customizing the GANA Model implementation in a phased approach enables to start with implementing autonomics via the centralized approach first (by the GANA Knowledge Plane autonomics) and benefit from that, while still leaving room (flexibility) for innovators to provide low level DEs for certain management and control aspects that require "fast control-loops" within NEs/NFs, while at the same time making the NE/NF level DEs be policy-controlled by the Knowledge Plane DEs

b) Hybrid approach to implementing GANA autonomics in networks
While in current networks phased approaches may be taken in implementing GANA autonomics, in future networks possibly a holistic non-phased approach might be taken, by which the low-level autonomics in NEs/NFs are considered at the same time as higher-level autonomics by the outer centralized Knowledge Plane and both getting interworked (similarly to the case of Hybrid SON (Self-Organizing Networks) implementation we see for the RAN (Radio Access Networks) today). ETSI 5G PoC White Paper No.1 [5] provides insights on how Centralized SON (C-SON) can complementarily interwork with Distributed SON (D-SON) in form of a Hybrid-SON model that is compatible with the GANA model. As mentioned earlier, a "top-down" and phased approach to implementing GANA autonomics levels could be suitable to some scenarios like the case of legacy network environments, while for white box networking (white boxes) and also for some NE platforms, there may be flexibility made available for the possibility that an innovator (the NE vendor itself or a third party) can inject GANA level 2&3 DEs into a White Box or NE(s) to execute as "local programs" using a local API (Application Programming Interface) provided by the White Box or NE vendor for enabling dynamic configuration of local MEs by such local programs introduced into the NE/NF. Such an internal API enables DE innovators to realize "fast control-loops" over local Managed Entities (MEs) and also realize "distributed control-loops" (DE algorithms) that scope a set of NEs along a path in network topology (if needed, because some aspects may be realized through a centralized DE algorithm running in the GANA Knowledge Plane instead).

c) Control-Loops Interworking consideration when implementing both Slow and Fast Control-Loops
Remark: What has to be considered in interworking the "Slow Control-Loops" by the GANA Knowledge Plane DEs and any "fast control loops" by GANA levels 2&3 that may be introduced at any time in some NEs is the **requirement that the GANA Knowledge Plane DEs shall policy control any low level DEs injected/implemented into an NE(s)**, and such policy control includes "activating" or "deactivating" the operations of those NE-internal DEs or their algorithms, and this could also mean that the KP should also configure the NE-local DEs to operate in either "open-loop" (by which the lower level DE compute recommendations that can be communicated into the KP without the lower level DE executing actions that can be derived from the actionable insights), or to operate in "closed-loop" mode instead. Apart from the well understood benefits of realizing "fast control-loops", low level DEs (GANA levels 2&3

DEs) could bring benefits of reducing the need for sending bulk telemetry/monitoring data from NEs/NFs to Data Collectors (Data Lakes) or to the Knowledge Plane Platform by sending out reports to the KP while still allowing certain amount of telemetry data to be sent out by the NE/NF to Data Collectors and/or to KP Platform(s).

d) Autonomics algorithms development as the "space" for DE innovation and DE supplier differentiation
DE innovators need to be given the flexibility to innovate autonomics algorithms, because "Centralized Algorithms" for Autonomics (implemented by the KP Level DEs) and "Distributed Algorithms" (implemented by way of GANA Levels 2&3) have their different benefits (e.g. with respect to convergence time and robustness comparisons, etc.). But both types of algorithms can be interworked using the GANA as Hybrid Model that enable to combine the two complementarily like has been achieved in the case of Hybrid SON (more details can be found in ETSI 5G White Paper No.1[5] and ETSI White Paper No.16[1]). Therefore, the GANA Framework allows for various options to be taken in implementing DEs in phased approaches or dependent on certain constraints of certain NE/NF vendor capabilities. A DE algorithm innovator may choose to implement the algorithm as a "Distributed Algorithm" to operate within NEs/NFs and also possibly as a distributed algorithm scoping certain NEs/NFs (e.g. NEs/NFs operating at certain boarder points between domains of a network topology using the Horizontal Reference Point (HRP) between the two DEs residing in the different NEs/NFs.

4. Cognitive-GANA-DE (AI Model) Vendor(s), Autonomic Management & Control Domain Expert(s), and Data Scientists, as Stakeholders bound by a DEs Production Ecosystem

The industry could now move to creating a "Market Place for Knowledge Plane Platform DEs and GANA level 2&3 DEs (thanks to White Box Networking and NE platforms that offer internal APIs for use by DEs implementers to introduce intelligence in NEs/NFs) to allow for acquiring and on-boarding best DEs with best algorithms for decision-making at any time during the lifecycle of the network or network element/function.

The following are other aspects that need to be considered by innovators and implementers of cognitive DEs:

- An AI Operations Model may specifically relate to a DE that exhibits AI algorithm(s) for Autonomics (AMC)
- A Deployment Repository may be deployed by a Network Operator as a Repository of Cognitive DEs (may include non-cognitive DEs as well)
- Policy Engine provides high level input policies to a Cognitive DE and the DE can generate low level policies from the input high level policies supplied as governance inputs by the human operator
- Performance Manager may be used by the Network Operator to perform performance management of each AI Component (e.g. Cognitive DE)
- An AI Model is at the core of a DE that exhibits AI algorithm(s) for Autonomics (i.e. Cognitive DE), while there is also the Option that DEs may have a commonly shared Cognition Module for Data Analytics that implements Data Analytics (at DE's run-time's Learning phase or Operation phase (at time of operating on real data)) while DEs use the Analytics outputs from the shared Cognition Module in their Decision-making processes and actions planning and executions
- Regarding Training Data Repository in relation to Developing and Training KP DEs, for the KP as AI System, the Data Training Repository must be populated by the datasets obtainable from the wide scope/diversity of data sources that constitute the "environment" (e.g. core network scope, just as example) in which the KP is expected to operate in, including the diverse events that may be desired to be visible for consumption by KP DEs algorithms and decision-making processes during its operation, as KP data sources should also include the variety(diversity) of management and control systems through which the KP DEs can be designed to consume events and/or execute autonomic operations that (re)-program the resources, parameters and services of the underlying network infrastructure(s) via the northbound interfaces exposed by such systems as described in [21].

- Training Data Repository for DEs meant to operate in NEs/NFs: for a single AI Component (e.g. Cognitive DE), the Training Data Repository must be populated by datasets from the scope/diversity of data sources that constitute the "environment" (e.g. NE/NF internal environment and external neighborhood as represented by the interfaces of the NE/NF) in which the AI Component (e.g. Cognitive DE) is expected to operate in, including the diverse events that may be desired to be visible for consumption by the DE's algorithms and decision-making processes during its operation , as well datasets from the variety(diversity) of the DE's Managed Entities (MEs) and other data sources from which the DE can be designed to consume inputs and/or execute autonomic operations that (re)-program its ME(s)
- As DE algorithms shall differentiate DE suppliers/vendors, the Data Training Repository contents will depend on the DEs that are meant to use it
- Cognitive Algorithms (Data Analytics Algorithms) can also be instrumented to run on Data Training Repository to synthesize Knowledge from the raw data and stream the Knowledge to consumer entities in different knowledge representation formats
- The following could be interpreted as one and the same thing: Data Training Repository and Data Collector; and Cognitive Algorithms can be instrumented to run on the Collector (Data Lake) to Generate Knowledge (Analytics results) that is streamed into the Knowledge Plane (KP) for KP DEs to consume and apply.

The industry now needs to implement the **New Concept of "Market Place for AI Models for AMC**".

4.1. Roles to be played by various stakeholders of GANA DE Ecosystems

This section lists and describes the roles to be played by various stakeholders as follows:

- *Data-Scientists;*
- *Researchers/Suppliers of AI Algorithms;*
- *Network Infrastructure Suppliers;*
- *5G Network Operators;*
- *Providers of Training Data Repositories for Training AI Models;*
- *Suppliers of GANA Decision-making-Elements (DEs) as "AI Models" that can be loaded into NEs/NFs or into Knowledge Planes (KPs) Platforms depending on the GANA level of the DE*
- *As such there is now the need to introduce the Concept of a "Market Place" for Cognitive GANA DEs as Deployable AI Models for AMC.*

Figure 5 presents the value creation at touch points (interfaces) between stakeholders of the AI Ecosystem. Each interface or touch point between two stakeholders can be translated into a contract reflecting a Business Model and value created and shared between Peer stakeholders. **NOTE:** In referring to **Figure 5**, TMForum is addressing this topic in TMForum IG 1180 document.

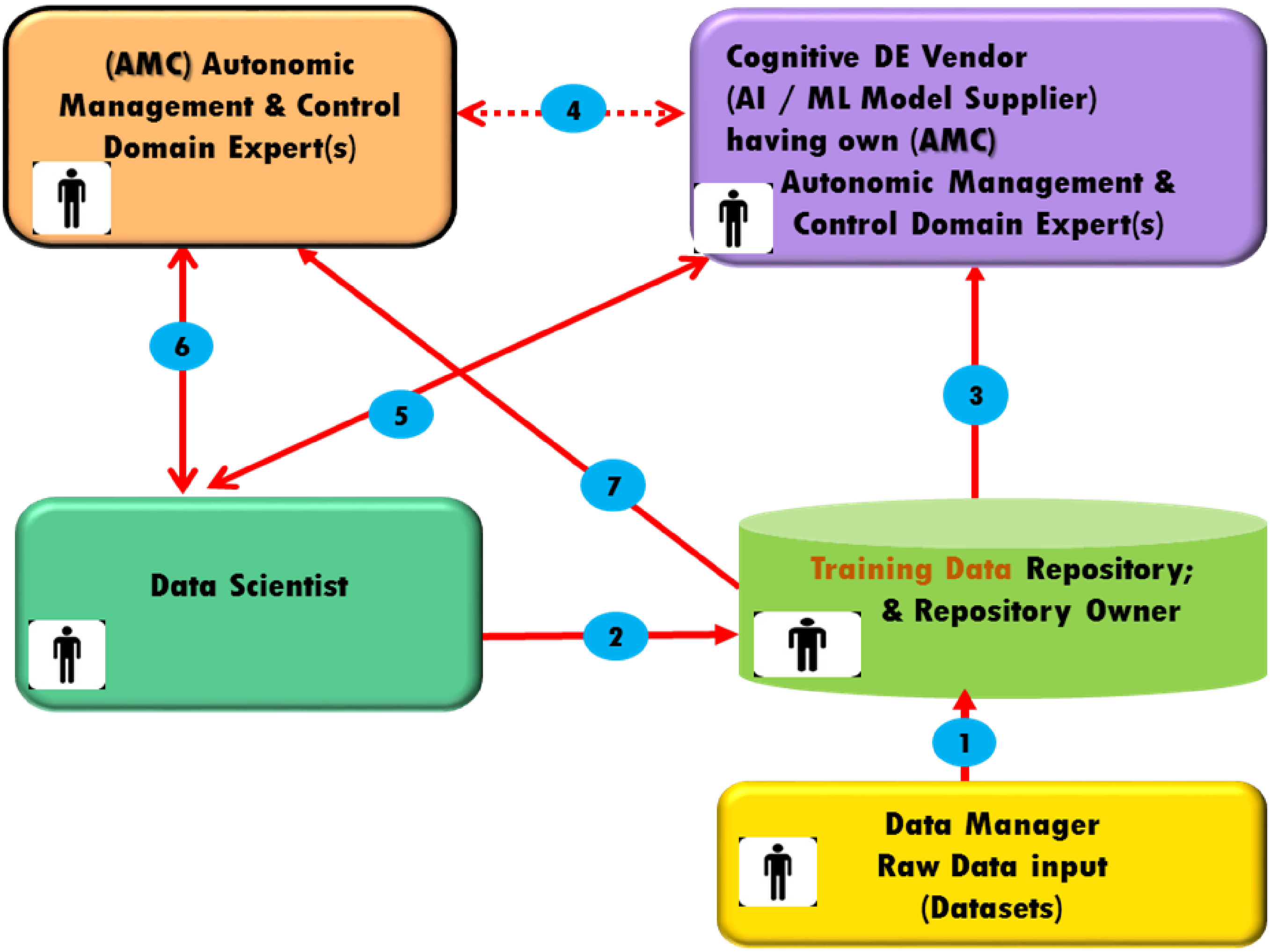

Figure 5: ***Interactions and relationships between GANA AMC (AI / ML) stakeholders that should be involved in the design and production of Cognitive AMC_DE(s)***

Examples of Types of Stakeholders that can play the specific roles in the context of Stakeholders that should be involved in the design and production of Cognitive AMC_DE(s):

- ***Cognitive-DE Vendor (AI Model Supplier)*** role can be fulfilled by a Network Infrastructure Vendor/Supplier of Network Elements/Functions (NEs/NFs) or a Vendor/Supplier of Network Management and Control Platforms (e.g. an Independent Software Vendor (ISV) or a Network Infrastructure Vendor/Supplier of Network Elements/Functions (NEs/NFs)). ETSI White Paper No.16 provides insights on the various potential suppliers of DEs as Software Modules/Components that can be loaded into NEs/NFs or into GANA Knowledge Plane Platform. However, Open Source projects may also be considered as "supplier" of AI Models such as Cognitive DEs
- ***Data Scientist*** *Role can be played by any competent experts that are able to provide Data Scientist Services*
- ***Training Data Repository Owner role*** *can be played by any Organization that may be trusted and neutral, e.g. Standardization Bodies or Fora (e.g. TMForum, ETSI, BBF, ITU-T, 3GPP, GSMA, IEEE, etc.) or even Open Source Projects*
- ***Data Manager*** *role can be any trusted entity that has a trust and business relationship with the Training Data Repository Owner*

4.2. Description of the Interactions between the Stakeholders

1) Data Manager collects and formats Raw Data and ensures Data Management requirements are fulfilled while interacting with a Training Repository Owner and the Training Data Repository
2) **Data Scientist instruments the Repository with Cognitive Algorithms (Data Analytics Algorithms)** for Data Ingestion and Knowledge Synthesis; and Clean Training Data to be delivered to con**sumer**
3) Input Data for training AI / ML Models (Cognitive DEs) are retrieved from the Training Repository
4) AI /ML Model Supplier partners with (AMC) Autonomic Management & Control Domain Expert(s), if Supplier does not have own Autonomic Management & Control Domain Experts for Design of Autonomic Management & Control Algorithms and Control-Loop Logics, and DE implementations thereof
5) AI / ML Model Supplier requests (partners with) Data Scientist to get support in preparing Training Data that would be required to train AI / ML Models (newly created or evolved ones (i.e. Cognitive GANA DEs for AMC)), if AI / ML Model Supplier does not have own Data Scientists to perform that task
6) Autonomic Management & Control Domain Expert(s) may engage Data Scientist in preparing Training Data and/or Knowledge Extraction from raw data, both for use in developing AI / ML Models and for developing other certain Algorithms for Autonomics' operations by Cognitive DEs
7) Autonomic Management & Control Domain Expert(s) may want to source Training Data for use in developing Autonomics Algorithms (Cognitive GANA DE's Algorithms)

4.3. Examples of Autonomic Management & Control (AMC) domains

The list below shows examples of Autonomic Management & Control (AMC) Aspects (involving knowledge on Implementing DE Autonomics (Control-Loops)) for which AMC Domain Experts should be engaged in Design and Implementations of Cognitive DEs

- ***Autonomic QoS-management & control domain—***implies the need to *Design/Implement Forwarding-Management_DE,*
- ***Autonomic Security-management & control domain***—implies the need to *Design/Implement Security-Management_DE,*
- ***Autonomic Mobility-management & control domain—***implies the need to *Design/Implement Mobility-Management_DE,*
- ***Autonomic Fault-management domain—***implies the need to *Design/Implement Fault-Management_DE,*
- ***Autonomic Resilience and Survivability management & control domain*** – implies the need to *Design/Implement Resilience & Survivability Management_DE,*
- ***Autonomic Service & Application management domain*** –implies the need to *Design/Implement Service & Application Management_DE,*
- ***Autonomic Forwarding-management & control domain—***implies the need to *Design/Implement Forwarding-Management_DE,*
- ***Autonomic Routing-management & control domain*** *—implies the need to Design/Implement Routing-Management_DE,*
- ***Autonomic Monitoring-management domain—***implies the need to *Design/Implement Forwarding-Management_DE,*
- ***Autonomic Monitoring-management domain*** –implies the need to *Design/Implement Monitoring-Management_DE,*
- ***Autonomic Generalized Control Plane management & control domain—****implies the need to Design/Implement Generalized Control Plane Management_DE*

NOTE: The various types of Decision Elements (DEs) listed above are defined in ETSI TS 103 195-2, and their associated mappings to their types of Managed Entities (MEs)—i.e. resources and configurable parameters that should be under the responsibility of the specific DE, are also defined in ETSI TS 103 195-2 and in concrete GANA instantiations onto a particular target implementation oriented network architecture and its management and control architecture (e.g. Broadband Forum (BBF) architectures(ETSI TR 103 473 V1.1.2), 3GPP Backhaul and Core Network (ETSI TR 103 404)).

5. ETSI GANA AMC_DEs (AI/ML Models) Marketplace Concept and Scope

Within the Digital Transformation journey for CSPs to become DSPs (Digital Service Providers), Marketplace Models are becoming key enablers. CSPs are embracing Digital Assets domain (Digital Services, Data, AI/ML Models Marketplace like being advocated for by ACUMOS Open source project [16])and are also embracing a new trend of trading Digital assets, EU Digital Service Marketplace, TMForum Distributed Ledgers / Blockchains Marketplaces. Some of them are steered by Open Source communities for co-innovation and rapid Time-to-Market purposes such as Acumos with Linux Foundation, Data Marketplace with IOTA Foundation to mention a few.

This section describes how ETSI GANA AMC DEs (AI / ML Models) could be produced, consumed and traded through a Marketplace model. We propose a broad picture of the stakeholders that should be involved in the design and production of Cognitive AMC_DE(s) and their interactions / relationships as depicted in Figure 5, and extended with other stakeholders that should play certain roles in the context of Test and Certification of Cognitive DEs, as well the DE Consumer side—namely Communications Service Provider (CSP and its internal Stakeholders involved in AI Strategy, AMC_DE (AI/ML Model) Procurement and Deployment Management..

Figure 6 provides the big picture on three perspectives (contexts) on the stakeholders that should be involved in each context, namely:

- *(1) Design, Development and Production of Cognitive AMC_DE(s) (AI / ML Models);*
- *(2) Test and Certification, Regulation / Legislation / Audit of Cognitive DEs (AI / ML Models);*
- *(3) CSP's internal Stakeholders involved in AI Strategy, AMC_DE (AI/ML Model) Procurement and Deployment Management.*

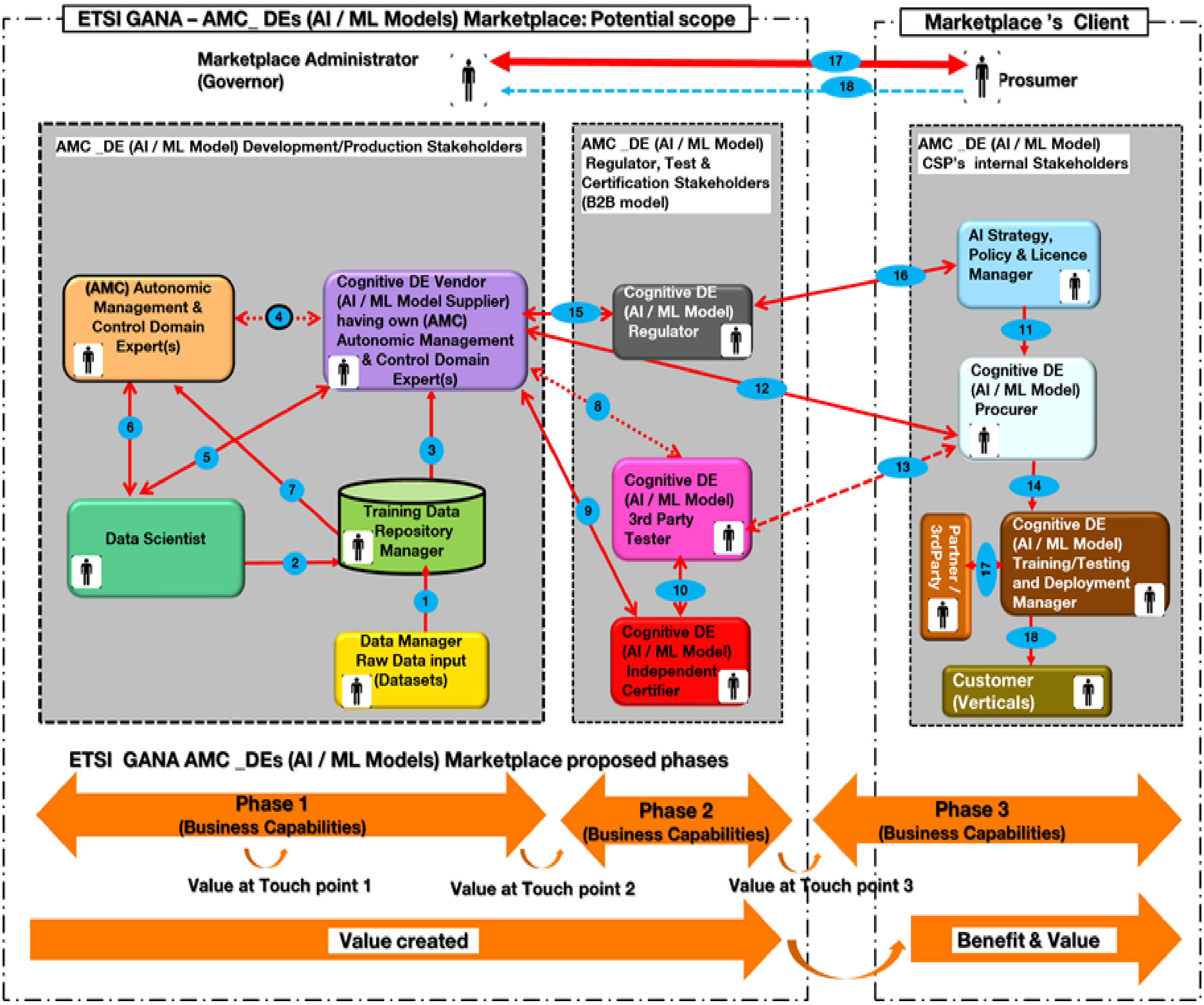

Figure 6: The Big Picture of ETSI GANA AMC DEs (AI / ML Models) Marketplace and Interactions and relationships between all key stakeholders

Proposed scope of the ETSI GANA AMC DEs (AI / ML Models) Marketplace: The Marketplace is a trading space where value stream is created and shared between the stakeholders involving and collaborating within this Ecosystem. What makes the difference with traditional ways of trading is the expected continuous value growth by sensing the market trend and then adding new business capabilities to meet Consumers' needs. This is the reason why we propose a phased approach to shaping the proposed scope as depicted in Figure 5.

- **ETSI GANA AMC DEs (AI / ML Models) Marketplace Phase 0 :** This phase is the current way of procuring GANA AMC DEs (AI / ML Models) by direct one to one interaction between AI / ML Models Supplier(s) and Consumer. The traditional RFP (Request For Proposal) process applies while considering this new asset, namely GANA AMC DEs (AI / ML Models), which are to be considered as Software. This phase is not shown in Figure 6(considered as base reference). In contrast to traditional software assets, a training process for an AI / ML Model requires input data that is as accurate as possible for Training the Model before deploying it in the Production Network. This task is performed out of Marketplace and is under the responsibility of the CSPs who is supposed to be owning the needed training Data.

- **ETSI GANA AMC DEs (AI / ML Models) Marketplace Phase 1 :** Figure 6 depicts the scope of this phase, the involved actors, and roles and responsibility demarcation. This phase aims at creating new business opportunities by engaging and onboarding the listed new actors that can provide the needed technical enablers that support the newly developed and introduced business capabilities. We depicted the touch points (interfaces) between the stakeholders involved in this ETSI GANA AMC DEs (AI / ML Models) Marketplace of this phase1. Each interface / touch point between two stakeholders can be translated into a contract reflecting a Business Model and value created and shared between Peer stakeholders. From process and AI / Model life perspective, this phase 1 corresponds to "AMC _DE (AI / ML Model) Development" phase. The additional enabler introduced in this phase is the Training process of the "AMC _DE (AI / ML Model)". Therefore, the Marketplace has the ability to offer this Training capability, hence it can be monetized.

- **ETSI GANA AMC DEs (AI / ML Models) Marketplace Phase 2 :** Figure 6 depicts the scope of this phase 2, the actors and roles and responsibility demarcation. This phase aims at creating new business opportunities by engaging and onboarding new actors that can provide the needed technical enablers that support the business capabilities to broaden the scope of Phase 1. From process and AI / Model life cycle perspective, this phase 2 corresponds to "AMC _DE (AI / ML Model) Test & Certification and Auditing". Those processes can be handled by independent stakeholders / Bodies **"**Independent Certifier of Cognitive DEs (AI Models)" offering certification services. Touch points/ Interfaces 8, 9, 10, 13, 15 involve stakeholders responsible of such certification services.

- **ETSI GANA AMC DEs (AI / ML Models) Marketplace Phase 3 :** Figure 6 depicts the scope of this phase 3, the actors and roles and responsibility demarcation. This phase is mainly focusing on the Marketplace's clients (CSPs) and its external interactions with the Marketplace stakeholders as well as the CPS's internal stakeholders that might have an impact on the Marketplace. We name this phase 3 as "AMC _DE (AI / ML Model CSP's Stakeholders". *External interaction with the Marketplace*: This interaction involves two actors, the Marketplace Administrator / Governor and the Prosumer. Indeed, there are CSPs that may play both roles 1) Client / Consumer, 2)A CSP in its new role of a DSP (Digital Service Provider or Software Company) during its Digital Transformation may become an AI / ML Model Provider. Interface 17 in Figure 6 represents this interaction. The types of CSP's internal Stakeholders (e.g. procurement and deployment departments) that should play certain roles in the context of Cognitive AMC _DE (AI/ML Model) life cycle processes include the ones listed below:
    - **AI Strategy, Policy & Licence Manager**
    - **AI Trainer & Tester of Cognitive DEs (AI Models)**
    - **Procurer of Cognitive DEs** (as Deployable AI Models or as AI Models already embedded in a Network Device/Equipment of Software Package)
    - **AI Deployment Manager**

  Additional Business capabilities to be implemented in Phase 3: In order to make the ETSI GANA AMC DEs (AI / ML Models) Marketplace self-governing w.r.t the Customer journey there is a need for embedding "Payment" and "Settlement" processes. That means those two processes while having been considered "Off-Marketplace" in Phase 2, when handled by the involved Stakeholders BSS / payment / Settlement applications and processes, they become "In-Marketplace" processes steered by the Marketplace itself..

- **Business Value for Marketplace:** The business value is continuously and incrementally growing when integrating a new Phase hence augmenting the exiting capabilities by new ones. This makes the Marketplace more attractive and offering added-value services over time, and this improves its reputation

- **Business Value for Marketplace stakeholder:** When the Marketplace builds a solid reputation, it attracts more stakeholders and the value created becomes larger and each stakeholder involved in this Ecosystem can augment its benefits

- **Business Value for CSP as Marketplace's Client:** It relieves the CSP from maintaining "Off-Marketplace" processes rather shaping pieces of a puzzle of interacting with required stakeholders which is time and cost consuming, hence the CSP relies on the whole "In-Marketplace" trusted and secure processes during the entire customer journey. The main benefit is zero-cost integration, fully agile journey, reducing time to market and focusing on value-added innovation, only.

6. The AMC Concept powered by AI/ML Capabilities

The figure (Figure 7) below illustrates how Cognitive GANA DEs (powered by AI / ML capabilities) can be developed. There are various mature approaches and insights now available in literature on how to design and implement AI Models for AMC (i.e. Cognitive GANA DEs), for example [20] and [22] and many more resources in literature provide insights. **NOTE:** On the Figure 7, the process "3" is not shown but is rather shown in Figure 9 and Figure 10**, as the process "3" involves onboarding the targeted "Procurable DE" from the DE Marketplace** and matching it to CSP's Metadata (Identification, Licensing model, Pricing model, Security, Traceability, Certification, Train /Test result and the constraining conditions, functional attributes e.g. required CPU, memory, dedicated GPU, …).

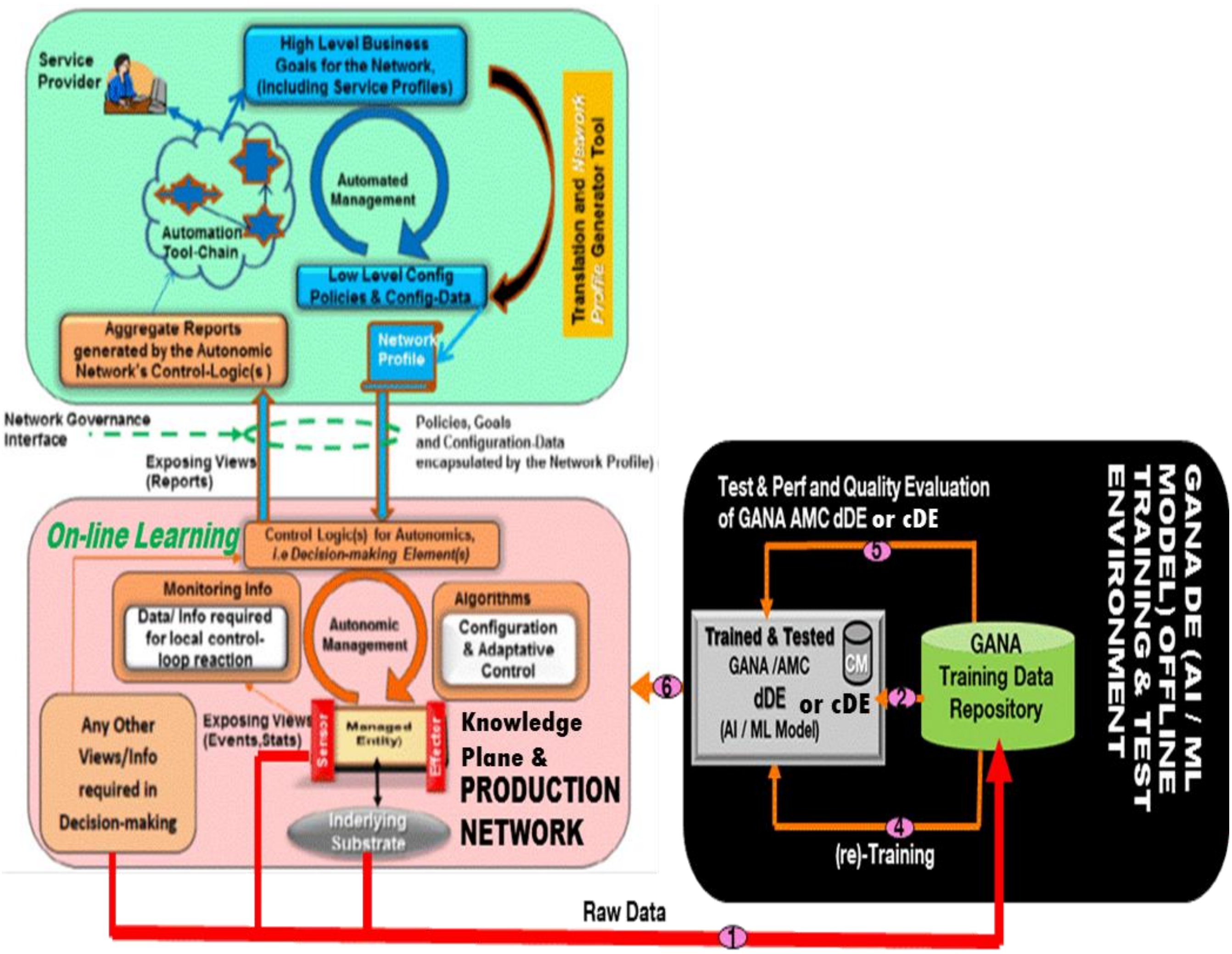

Figure 7: ***ETSI GANA AMC paradigm powered by AI / ML capabilities***

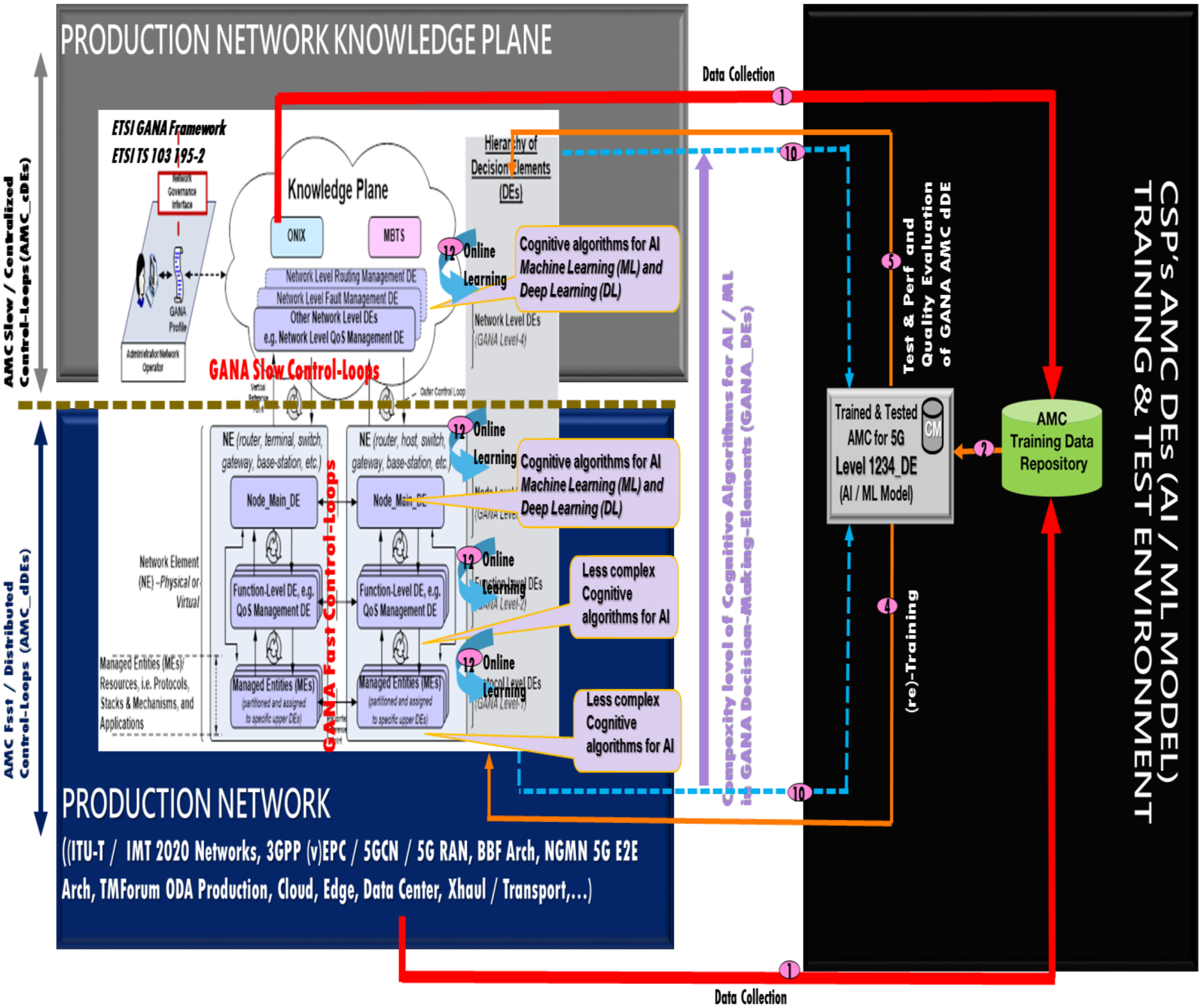

Figure 8: ***ETSI GANA as Multi-Layer Artificial (AI) Framework for Implementing AI Models for AMC of Networks and Services***

7. Lifecycle Management Framework for a Cognitive GANA DE as an AI/ML Model for realizing specific AMC Objectives

7.1. Overview

According to ETSI GANA AMC and its AI/ML Framework there are three categories of an AMC DE as AI/ML Model in the AMC Multilayer Framework, namely: either dDE (Distributed DE deployed and executed in a Network

Element/Function (NE/NF)) or cDE (Centralized DE implemented in the realm of the outer management and control systems called the Knowledge Plane of a specific Network Segment). ETSI GANA framework describes how cDEs (called GANA Knowledge Plane DEs) interwork with dDEs by way of cDEs performing policy control of dDEs in NEs/NFs.

7.2. Use Case 1: Lifecycle Management of "Network Element/Function (NE/NF)- embedded/local" distributed GANA dDE

The following aspects (three categories (status) of a Cognitive GANA DE) pertain to Lifecycle of Cognitive DEs (for both dDE or cDE):

- **"Procurable" Cognitive AMC_DE (AI / ML Model**): made available in the Marketplace and ready for onboarding by the Network Operators for internal complementary training and testing of the dDE before moving to Production Network in which the dDE is put in operation. The same is expected of a cDE of a Knowledge Plane Platform, before it can be put into operation as an integral part of the Knowledge Plane Platform to be put into operation.
- **"Trained and Tested" Cognitive AMC _DE (AI / ML Model)**: Procurable AMC dDE (AI/ML Model) or a cDE (AI/ML Model) has passed Training and testing and Quality evaluation in the Network Operator's Training and Test environment (Offline Training) and declared as "operations ready", and ready for deployment in Production Network (in the case of cognitive dDEs) or in the Knowledge Plane Platform (for cDEs—always expected to be cognitive)
- **"Deployable" Cognitive DE (AI / ML Model):** when Training and Testing team declares this status, the AMC dDE (AI / ML Model) is instantiated in the Production Network and consumes Real Data and Events from the Production Network and is made to interwork with other DEs and any other integration components it needs to work with. The same is expected of a cDE of a Knowledge Plane Platform, before it can be put into operation as an integral part of the Knowledge Plane Platform that is to be put into operation.

NOTE: Along with the "Offline GANA AMC dDE (AI/ML Model)" we may have at the same time "Online GANA AMC dDE (AI / ML Model)" instances running while subjected to an "Online learning" process as depicted by interface "12" in the figure below (Figure 9). The same applies for a cDE (i.e. an "Offline GANA AMC cDE (AI/ML Model)" and "Online GANA AMC cDE (AI/ML Model")).

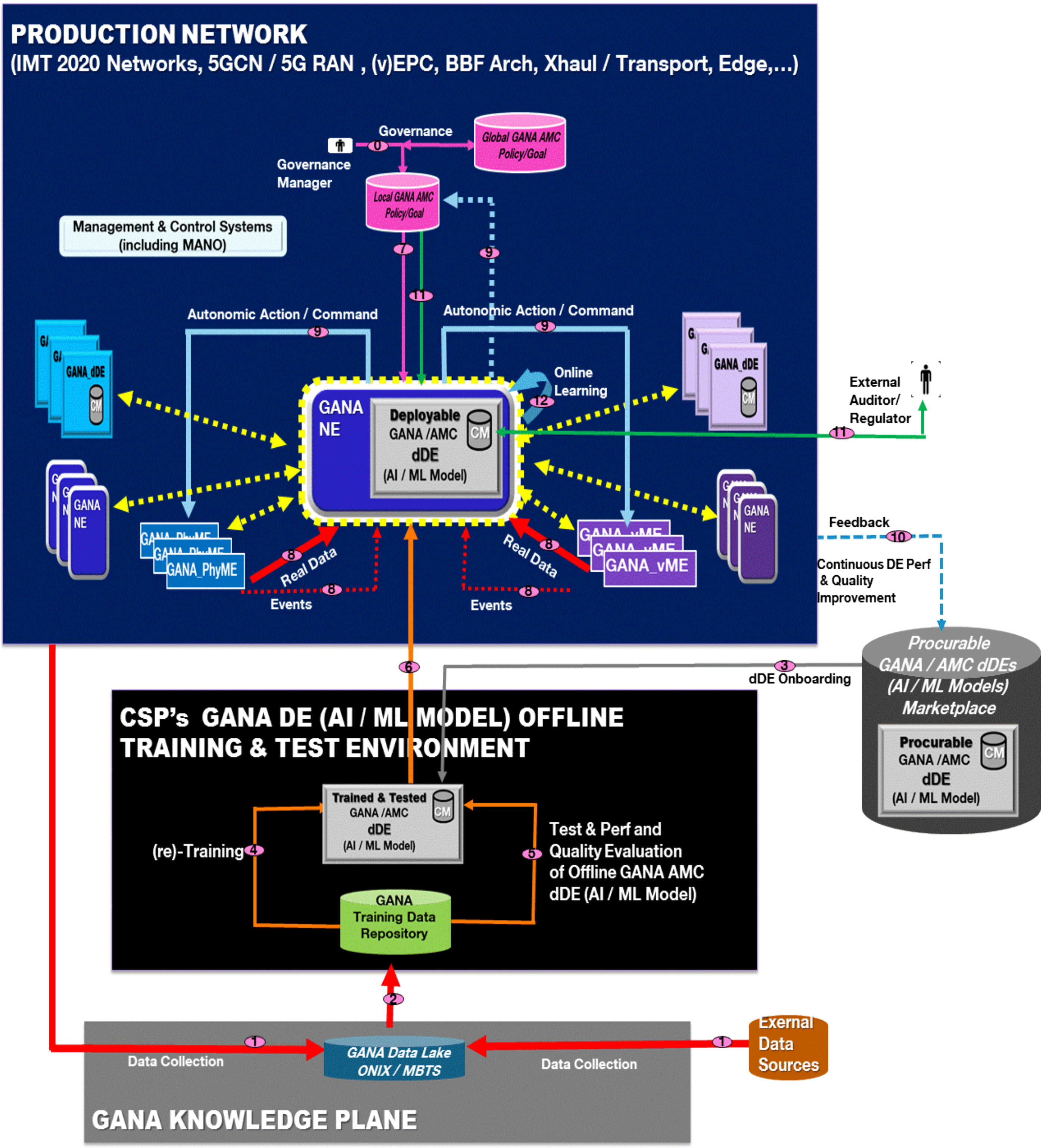

Figure 9: Lifecycle of *an NE/NF- local(embedded) / distributed GANA AMC dDE (Decision Making Element) (AI / ML Model)*

Descriptions of the Process WorkFlows for the Cognitive DE lifecycle Management: While the lifecycle management aspects below are mainly focused on a Distributed DE (dDE) but with indications of aspects that also apply to the case of a cDE, the more detailed lifecycle management of Knowledge Plane DE (called a centralized Decision making Element (cDE)) as a Cognitive DE for AMC (a deployable (AI/ML Model)) can be found in section 7.3.

0) **Governance Function (Dashboard):** it is an instrument that allows the CSP (Governance Manager) to define Business Policies, Objective /Goal and Intent specifications to be enforced and executed to ensure an optimal operation and achievement of desired objectives by autonomics services of the DEs while keeping control of activation / de activation of deployed DEs (AI /ML Models), conflicts resolution that may be required and all associated accountability and responsibility aspects related to supplied Data and DEs (AI /ML Models)
1) **GANA AMC Data Lake (realized by ONIX, MBTS, and Data Collectors in general):** It is a source of Datasets (Raw Data). It is populated by Raw Data collected from Production Network and complemented by External Data Sources
2) **Data Training Repository:** Various Datasets must be considered in populating the Data Training Repository in order to produce clean and accurate Data and also synthetize(extract) knowledge from the data and make the data or extracted knowledge available for a GANA AMC dDE(s) or a cDE(s) (AI / ML Models) training and testing processes
3) **Onboarding the targeted “Procurable dDE” or “Procurable cDE” from the dDE or cDE Marketplace** and matching it to CSP’s Metadata (Identification, Licensing model, Pricing model, Security, Traceability, Certification, Train /Test result and the constraining conditions, functional attributes e.g. required CPU, memory, dedicated GPU, …)
4) **Training: Training Data Repository output enables training** a single AI / ML Model Component (e.g. Cognitive dDE or cDE) with accurate Data sets in the CSP’s Training & Test Environment and produces a viable trained dDE that can be deployed into the Production Network (live operations), or a viable trained cDE that can be activated/onboarded into the Knowledge Plane (KP) Platform
5) **Testing and Evaluating dDE Performance and its Quality of “Decision-Making Capability”** against the expected /predicted targets (prescribed by the CSP) in the CSP’s Testing Environment before declaring and certifying it as “operation ready” and “deployable dDE” for injection into a Network Element/Function (NE/NF) in the Production Network. The same is expected in the case of a cDE, i.e. of Testing and Evaluating a cDE Performance and its Quality of “Decision-Making Capability” before declaring and certifying it as “operation ready” and “deployable cDE” for activating/onboarding into the Knowledge Plane (KP) Platform.
6) **Deployable GANA AMC dDE (AI / ML Model) is transfered to** Production Network as a trained and tested dDE for deployement and operation together with other DEs in the NE/NF. In the case of a deployable cDE, is activated/onboarded the into the Knowledge Plane (KP) Platform to operate and interwork with other cDEs in the Knowledge Plane (KP) Platform.
7) **Business Policies / Goal(s):** Prescribed by the CSP at Global and Business level (Intra and Inter Domain) but interworking/coordinating/ synchronizing with local level (Production Network) to drive the GANA / AMC dDE or cDE lifecycle to achieve the objective and the desired service the DE is designed to offer, and such policies or goals may be (re) adjusted during the course of the lifecycle.
8) **Operations of dDE with real Data and Events:** Scope/diversity of real (run-time) data sources that constitute the “environment/proximity/neighborhood” for the dDE (namely its Production Network_Managed Entities (GANA_vMEs, GANA_PhyMEs), network element’s neighborhood and internal environment of the Network Element in which the AI Component (i.e. the Cognitive GANA_dDE**)** is designed to operate in. Datasets from the various data sources should include diverse events types that may be desired to be visible for consumption by GANA_dDEs algorithms and decision-making processes during its operation. The variety (diversity) of the dDE’s Managed Entities (MEs) are part of the Data sources from which the GANA_dDE is designed to consume inputs and then execute autonomic operations that (re)-program its ME(s) (GANA_PhyMEs and GANA_vMEs). In the case of Operations of a cDE with real Data and events, the cDE (in the Knowledge Plane) is fed by its lower level dDE(s) it is responsible of policy controlling as well as data and events coming from systems and components that should be integrated with the GANA Knowledge Plane Platform as described in section 1.1 and in the ETSI INT AFI 5G Report [21]. More details in the case of a cDE are found in section 7.3.

9) **Autonomic Action / Recommendation:** dDE executes autonomic operations that (re)-program its GANA_ME(s) (GANA_PhyMEs and GANA_vMEs) that it policy-controls according to the ownership mapping process defined in ETSI TS 103 195-2, and the DE re-programs its MEs in reaction to receiving any updates/changes to the Production Network Policy. The dDE may interact with other dDEs. This aspect of "autonomic action/recommendation" also applies to the case of a cDE, with a dDE(s) being viewed by a cDE as a Managed Entity (ME) that needs to be policy controlled or orchestrated by the cDE (according to "DE-ME ownership principles" defined in ETSI TS 103 195-2).
10) **Feedback to GANA AMC DE (AI/ML Models) Marketplace**: Provide output / suggestion / lessons learned after operating the dDE or cDE to the dDE or cDE Marketplace to help the supplier to continuously improve the performance and "quality of decision-making capability" of the dDE or cDE and the resultant action could be reloading /upgrading to a better dDE or cDE version
11) **Audit:** an Audit campaign could be launched and then a Report is produced by the main Coordinator DE of an NE/NF that coordinates all dDEs instantiated in the NE/NF (e.g. indicating the percentage of deployed dDEs that are not achieving their objectives and why e.g. due to policies conflicting under certain situations or as a result of challenges the network may be experiencing, etc.). The Report produced by an Audit operation is also to contain KPIs on how each dDE is fairing in achieving its Objectives and how all the dDEs are collectively working together to achieve the global policy/goal or an "intent" provided to them as input by the CSP. An external Audit could be launched by an Auditor/Regulator and Report is produced on Supplied Data, and deployed DEs (AI/ML Models) from provenance accountability and responsibility. The aspect of "Auditing" a DE also applies to a cDE (by the coordinator DE in the associated Knowledge Plane scope), and more details in the case of a cDE, including how "intent" is provided as input to the Knowledge Plane rather, are found in section 7.4.

7.3. Use Case 2: Lifecycle Management of a GANA Knowledge Plane DE (called a centralized Decision making Element (cDE) as a Cognitive DE for AMC (as deployable (AI/ML Model)

The figures below (Figure 10 and Figure 11) illustrate Lifecycle Management of a GANA Knowledge Plane DE (called a centralized Decision making Element (cDE) as a Cognitive DE for AMC (as deployable (AI/ML Model).

Descriptions of the Process WorkFlows for a Knowledge Plane DE (cDE)—a KP DE always has to be a Cognitive DE according to ETSI TS 103 195-2: The interaction flows below are the ones specific to the case of a cDE (a Knowledge Plane DE), while the other flows described for the case of a dDE also apply to a cDE:

0) **Governance Function (Dashboard):** it is an instrument that allows the CSP (Governance Manager) to define Business Policies, Objective /Goal and "***Intent***" specifications to be enforced and executed to ensure an optimal operation and achievement of desired objectives by the cDE services while keeping control of activation / de activation of deployed DEs (AI/ML Models), conflicts resolution that may be required and all associated accountability and responsibility aspects related to supplied Data and DEs (AI / ML Models)

7) **Business Policies / Goal:** Prescribed by the CSP (Governance Manager) at Global and Business level (Intra and Inter GANA Domain) but interworking/coordinating/ synchronizing wth local level (Production Network or a Single GANA Domain instance) to drive the GANA_cDE lifecycle to achieve the objective and desired service the DE is designed to offer and such policies or goals may be (re) adjusted during the course of the lifecycle.

12) **DEs coordination and DE-to-DE chanining Choreography:**/ DE-to-DE Collaboration in form of a Chereography, by exchange of information and or negotiations on parameter values adjustments on various MEs associated with the various collaborating DEs in order to achieve the global Autonomics and AI/ML Objective. This is driven by a Superior/Designated cDE (*Network Level AutoDiscovery_&_AutoConfiguration-DE* (also called *AutoConfiguration_&_AutoDiscovery-DE*)) that policy-controls the other DEs involved in the chaining of the DEs at Knowledge Plane Level. **NOTE:** At NE/NF level a superior DE (the NE/NF level AutoDiscovery_&_AutoConfiguration-DE (also called AutoConfiguration_&_AutoDiscovery-DE)) is required to perform the coordination of the dDEs for certain operations that require the dDEs to be coordinated. More details on this subject are provided later in section 7.4.
13) **Execution of DE-to-DE Chaining:** the realization of the DEs chaining that ensures conflict-free implementation of AMC operations
14) **Online Learning DE (AI / ML Model)**: For Online dDE (AI / ML Model), a feedback to get approval/ validation/ Reject of the execution of recommendation by the cDE responsible for policy-control of the dDE

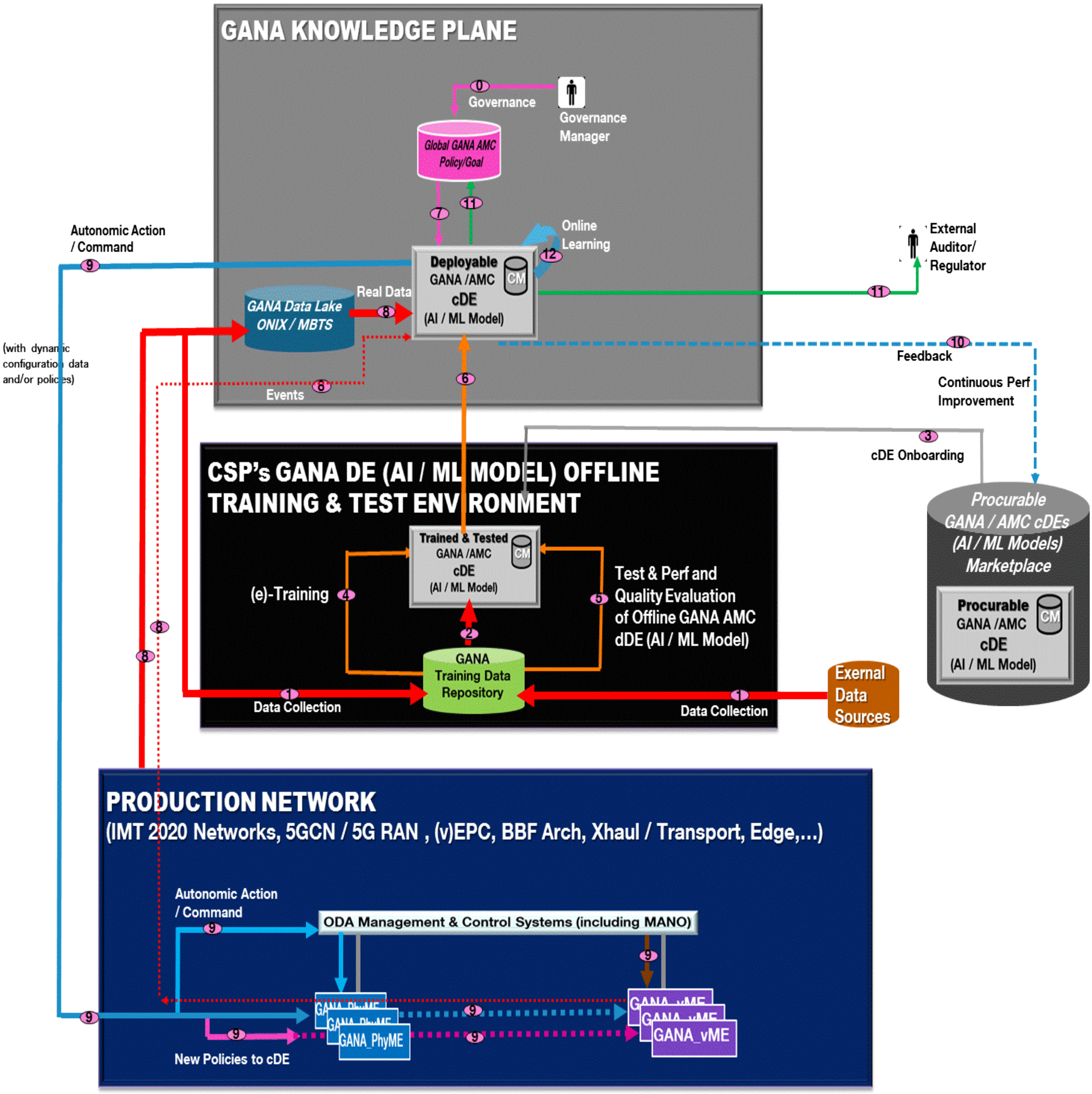

Figure 10: *Use Case 2: GANA AMC Knowledge Plane cDE (centralized Decision making Element) Lifecycle*

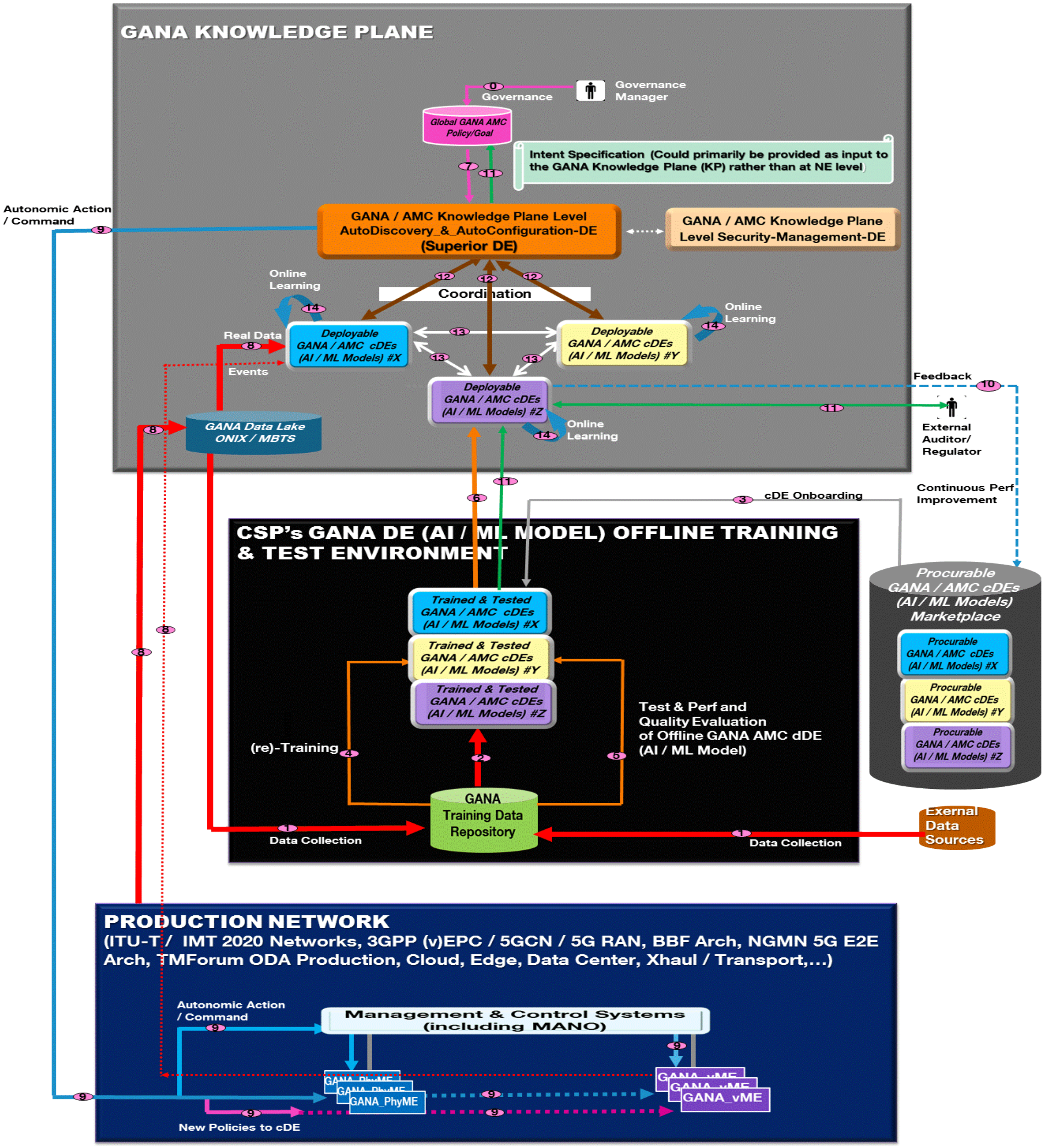

Figure 11: *Knowledge Plane Level Choreography of DE-to-DE Coordination and Chaining by a Superior/Designated cDE*

Remark: NE/NF Level Choreography of DE-to-DE Coordination and Chaining by a Superior/Designated dDE is illustrated in section 7.4.

7.4. On DE Coordination by a Superior/Designated dDEs or cDEs, and how "Intent" as Input should be handled in the ETSI GANA Framework

Figure 12 presents DE Coordination by a Superior/Designated cDE, and how "Intent" as Input should be handled in the ETSI GANA Framework, and Figure 13 presents DE Coordination by a Superior/Designated dDE, and how "Intent" as Input should be handled in the ETSI GANA Framework. These aspects of DE coordination within the scope of the Knowledge Plane and within the scope of an NE/NF, as well as how intent as inputs should be handled in the ETSI GANA Framework are described below:

- In ETSI GANA, the Knowledge Plane(KP)-Level *AutoDiscovery_&_AutoConfiguration-DE* (also called *AutoConfiguration_&_AutoDiscovery-DE*) is the Superior Coordinator of the operations of cDEs in the Knowledge Plane in collaboration with the Security-Management-DE that determines and enforces security in the various communications. It resolves conflicts and provides the cDEs with goals and policies translated from an Intent provided as input by the CSP. But each of the cDEs can also be designed to derive and compute the goals and policies intended for its scope from the Intent provided as input by the CSP.
- In ETSI GANA the KP-Level *AutoDiscovery_&_AutoConfiguration-DE* also interacts with its "mirror" NE-level *AutoDiscovery_&_AutoConfiguration-DE* injected to operate in a NE/NF, to provide it with goals and policies for the dDEs in the NE/NF. Even though policies are expected to be dynamically generated by cDEs and relayed to their corresponding "mirror" dDEs either directly to the NE-level *AutoDiscovery_&_AutoConfiguration-DE* as an interceptor that then passes them to local dDEs in collaboration with the Security-Management-DE that ensures that the communications of the NE's dDEs with the external KP passes security requirements. Alternatively, the policies are directed by the cDEs to the KP-Level *AutoDiscovery_&_AutoConfiguration-DE* as higher level interceptor that then sends them to the target NE-level *AutoDiscovery_&_AutoConfiguration-DE* that then dispatches them to local dDEs if security checks against the security policies enforced by the local Security-Management-DE have passed.
- If an Intent was to be provided by the CSP directly on the level of an NE and not inductively through the Knowledge Plane as input point, then NE-level *AutoDiscovery_&_AutoConfiguration-DE* is the Superior Coordinator of the operations of dDEs in the NE. It resolves conflicts and provides the dDEs with goals and policies translated from the Intent provided as input by CSP but each of the dDEs can also be designed to derive and compute the goals and policies intended for its scope from the Intent provided as input by CSP.
- In general, the *AutoDiscovery_&_AutoConfiguration-DE* in the Knowledge Plane and its "mirror" *AutoDiscovery_&_AutoConfiguration-DE* in an NE/NF, could act (at the DE's respective level) as an orchestrator of the other DEs (including enabling/disabling, stopping or temporarily pausing their operations) and at the same time performing coordination of the operations of the other DEs
- Collaborative Optimizations at NE level and also at Knowledge Plane Level is required, and at each of the two levels the Coordinator DE (*AutoDiscovery_&_AutoConfiguration-DE*) may need to employ certain Optimization Algorithms that optimize and perform ordering of certain Actions or Plans of Actions computed by the DEs it coordinates before the DEs are allowed to execute the Actions

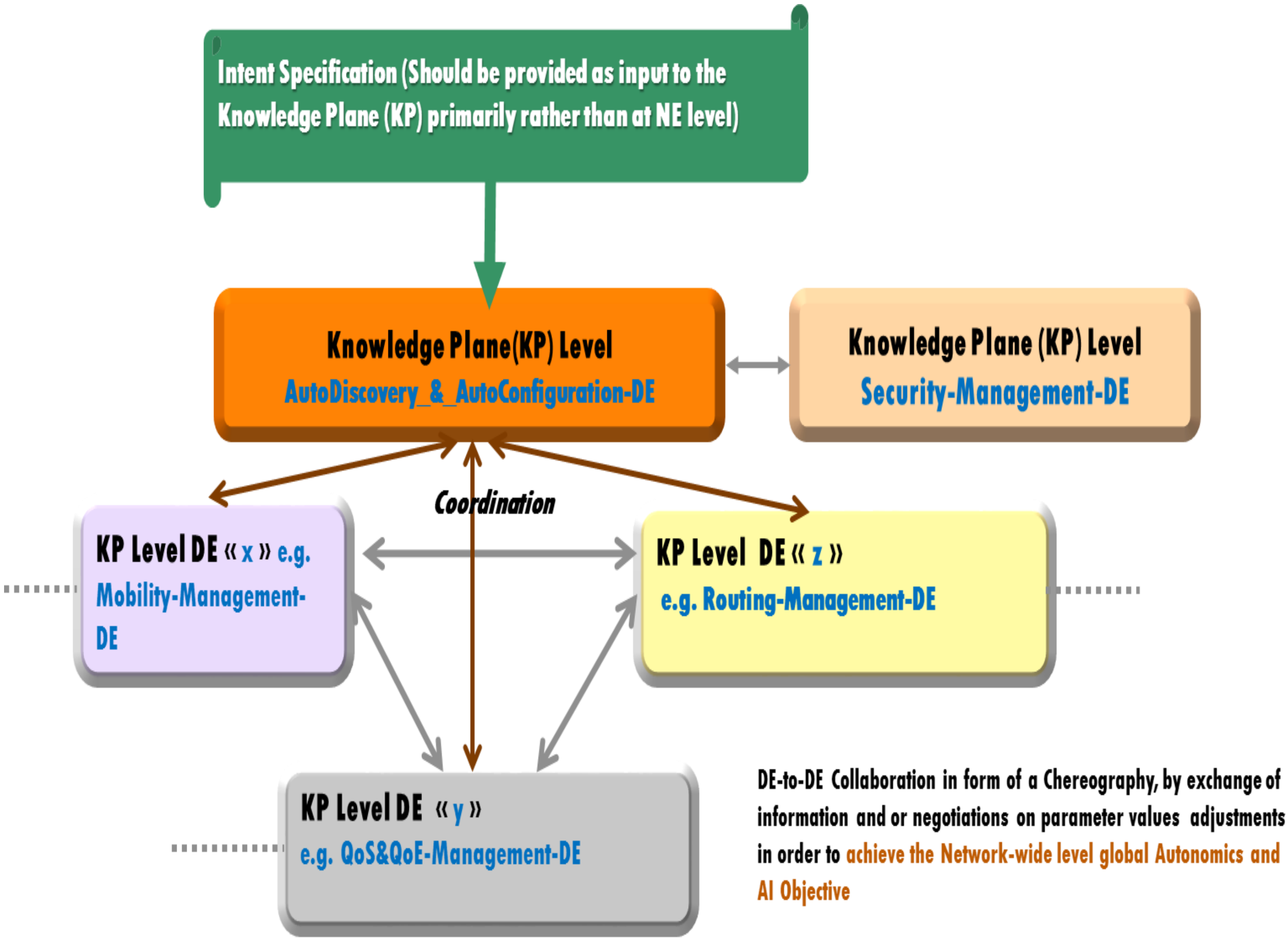

Figure 12: ***DE Coordination by a Superior/Designated cDE, and how "Intent" as Input should be handled in the ETSI GANA Framework***

<u>**NOTE:**</u> The **KP Level (Network-Level)** ***Security-Management-DE*** dynamically maintains knowledge of security threats/risks, detected attacks and impacts on the network, as well as dynamically computing and applying security policies for self-protection and self-defense for the network. Such security related information may need to be shared by the Security-Management-DE directly to the other DEs so that they take into consideration such information in their autonomic decisions, or the Security-Management-DE dynamically relays such information to the **KP Level (Network-Level)** ***AutoDiscovery_&_AutoConfiguration-DE*** that then dispatches the information to the other DEs and/or takes into consideration such security related information in its tasks of coordination of the KP DEs' operations. The White Paper [23] provides insights on the complete functionality of the ***Security-Management-DEs.***

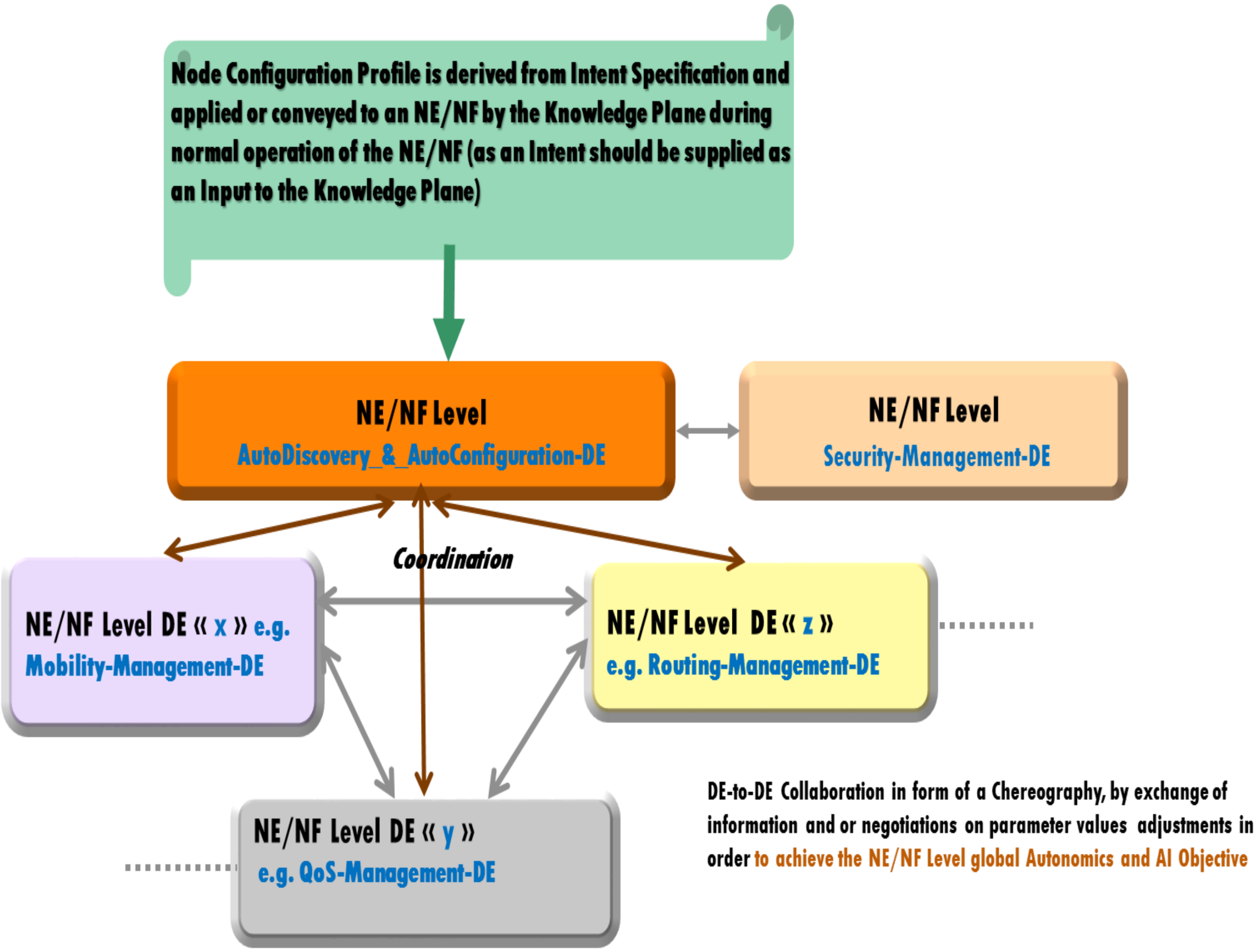

Figure 13: ***DE Coordination by a Superior/Designated dDE, and how "Intent" as Input should be handled in the ETSI GANA Framework***

NOTE: The ***NE-Level Security-Management-DE*** dynamically maintains knowledge of security threats/risks, detected attacks and impacts on the network, as well as dynamically computing and applying security policies for self-protection and self-defense for the network. Such security related information may need to be shared by the Security-Management-DE directly to the other DEs so that they take into consideration such information in their autonomic decisions, or the Security-Management-DE dynamically relays such information to the ***NE-Level AutoDiscovery_&_AutoConfiguration-DE*** that then dispatches the information to the other DEs and/or takes into consideration such security related information in its tasks of coordination of the KP DEs' operations. The White Paper [23] provides insights on the complete functionality of the ***Security-Management-DEs.***

7.5. Use Cases of Federated AMC Knowledge Planes (Inter-Domain and Inter Operator option for E2E Network Slice Autonomic Service and Security Assurance

7.5.1. Overview

From Business perspective, such use cases described in this section relate to Dynamic Network Slice Management through Autonomic Service and Security Assurance process powered by AI capabilities as a means for CSPs to fulfil the requirements of Vertical Industries (e.g. Industry 4.0, Automotive, Banking, Insurance, Smart Cities, etc.) while deploying and operating a single 5G Network that is either partitioned into Multiple Domains or is based on federated Multiple Operators' 5G Networks whenever required.
Examples of Verticals' applications' SLA requirements are "Predictive QoS" for Automotive / V2X applications and "Time Sensitive KPIs" for Industry 4.0 that must be timely guaranteed, dynamically and the on-fly (re)- negotiated against capabilities of a 5G Network. This is similar to the traditional process of SLA Management (Negotiation, Operations / Execution / Enforcement, Report) as documented in the document by TMForum (IG 1127 "End-to-End Virtualization Management: Impact on E2E Service Assurance and SLA Management for Hybrid Networks") [24]. Indeed, both the "contractual" SLA between two parties (a Customer and a Provider) and the technical-level QoS requirements characterization use one common description template: the SLS (Service Level Specification), which is a detailed list of Metrics ("SLS Parameters") and associated SLS Thresholds (used for triggering SLS Consequences when expected service levels are not met). SLS Thresholds are informally also known as SLO (Service Level Objective).
Network Slice as a "product" that is meant to be provided and consumed is associated with SLAs hence is also to be subjected to this SA Management process (refer to TMForum IG 1127 "End-to-end Virtualization Management: Impact on E2E Service Assurance and SLA Management for Hybrid Networks")[24] in accordance to GSMA document GSMA Generic Network Slice Template Version 1.0, 23 May 2019 [25] and 3GPP 5G terminology document 3GPP TS 28.531, V16.0.0 (2018-12): "Management and orchestration; Provisioning" [26].
This section reflects this aspect at the left hand side (green part) of the three Figures 14, 15, 16. Indeed, the negotiated SLA that is agreed between Network Slice Producer and the Vertical (slice consumer) aims at matching the particular Vertical Industry's SLA requirements with 5G Network Slice Producer (5G Operator(s)) capabilities as depicted by (a). The result of the negotiation process leads to the agreed result depicted (b). This is achieved by successively instantiating (populating different fields with values or range of values) from GSMA GST (Generic Slice Template) depicted by (c), GSMA NEST (Network Slice Type) depicted by (d), 3GPP NST (Network Slice Template) depicted by (e) (in reference to 3GP TS 28.531) [26] from which one can derive multiple Network Slice Instances. The Phase depicted by (f) corresponds to injection and autonomic orchestration and self-monitoring of the SLA by the 5G Network's autonomic service and security assurance capability. This NEST corresponds to the "5G Design Template" defined in the description of the high level design principle of the ETSI TC INT 5G PoC ecosystem and associated actors/roles relationships and interactions as depicted in Figure 12 of 5G PoC White Paper N°3 [17]. Its translation onto the required network slice resources by the E2E Service Orchestrator per Network Slice Instance corresponds to the NST.
The Phase depicted by (g) corresponds to the real-time reporting of the status of consumed Network Slice Instances by making available to the involved Verticals (Networks Slice Instances Consumers) customized Real-Time (RT) Dashboards on consumed 5G Network Slices per Network Slice Instance, per Application, per Device according to the particular Vertical Industry's request.
This continuous adjustment and updates of the SLAs is realized through GANA's AMC Multi-Layer / Nested Control-Loops) Federated Framework. The ETSI 5G PoC White Paper No.3 [17] on 5G PoC Programmable Traffic Monitoring for Network Slices Service Assurance provides a detailed description, implementation and demonstration of this use case.
Besides this Dynamic SLA Management process described in this section involving Network Slice Provider and Vertical Industries as Slices Consumers, the process also involves the CPS's internal stakeholders (Inter-Domain model Figures 14 and Figure 15) where internal SLA named OLA (Operational Level Agreement) at touch points between 5G Domains depicted by (h) is managed. In the Intra Operator model (Figure 16), there is also SLAs at the touch points depicted by (i).
It may happen that 3rd Parties (e.g. SLA Broker) play certain roles between Slice Provider and Consumer by offering SLA Management services or certain SLA responsibilities might be delegated to them by one or more of the main parties. The SLA Broker is connected through dotted lines depicted by (j) as depicted in Figure 16. Those four lines represent the respective potential SLA contracts (from negotiation to execution, and then to reporting).

In terms of design principle illustrated by the diagrams in the Figures 14, 15 and 16, the use cases of federated AMC Knowledge Planes (KPs) follow the same approach as the ones described in section 7.1, 7.2, 7.3, 7.4, with consideration

of CSP (s)' Autonomic Production Network and related Training & Testing Environment for GANA AMC DEs / AI Models and the involvement of external stakeholders such as GANA-AMC DEs Marketplace stakeholders, Auditor / Regulator, etc.
Two main Options and Scenarios are considered in the Federated AMC use cases:

- Option-A: Horizontal Federation of Knowledge Planes in Inter-Network Segments KP Domains model (Single Organization Scenario)
- Option-B: Vertical (Hierarchical) Federation of Knowledge Planes in Inter- Network Segments KP Domains model (Single Organization Scenario)
- Option-B: Vertical (Hierarchical) Federation of Knowledge Planes in Inter-Operator model (Multi Organization Scenario)

What is common to those options:

- **F-MBTS**: A federation translation function (F-MBTS) defined in ETSI TS 103 195-2 may be required if data models and communication methods for federations employed by the two or more domains are different
- **AMC-MBTS:** It is a translation function (defined in ETSI TS 103 195-2) placed between the Network Elements/Functions (NEs/NFs) of the Network Layer and the Knowledge Plane (KP).
- **ONIX:** is a Knowledge Base (consisting of a federation of Information Servers that collectively provide "*Publish/Subscribe*" and "*Query/Find*" services to entities that such services in auto-discovery objectives) that can act as a Real-Time Inventory. In the Inter- Network Segment KP Domains model (within Single Organization) a unique and shared ONIX may be the option. In the Inter-Operator model (Multi Organization Scenario) having standalone ONIX instances is the appropriate approach as each Operator needs to own its own Knowledge base, and Data in the ONIX instances may be structured in a specific format that could be different for each operator specific ONIX instance of the Operators engaged in the federation.

7.5.2. Option-A (Horizontal Federation of KPs) in Inter-Network Segment KP Domains model (a single Organization Scenario)

It is the option by which the GANA Knowledge Plane (KP) Platforms for the specific network segments (e.g. 5G RAN, X-Haul Transport, 5G Core Network) federate horizontally with each other without the need for an overlay umbrella Hierarchical GANA Knowledge Plane (KP) Platform.
In such an option there is a need for an Interworking / Coordination Reference Point for E2E Federation of the Knowledge Planes (e.g. 5G RAN-KP, Xhaul Transport-KP, 5G Core Network – KP.
Figure 14 depicts this option A.

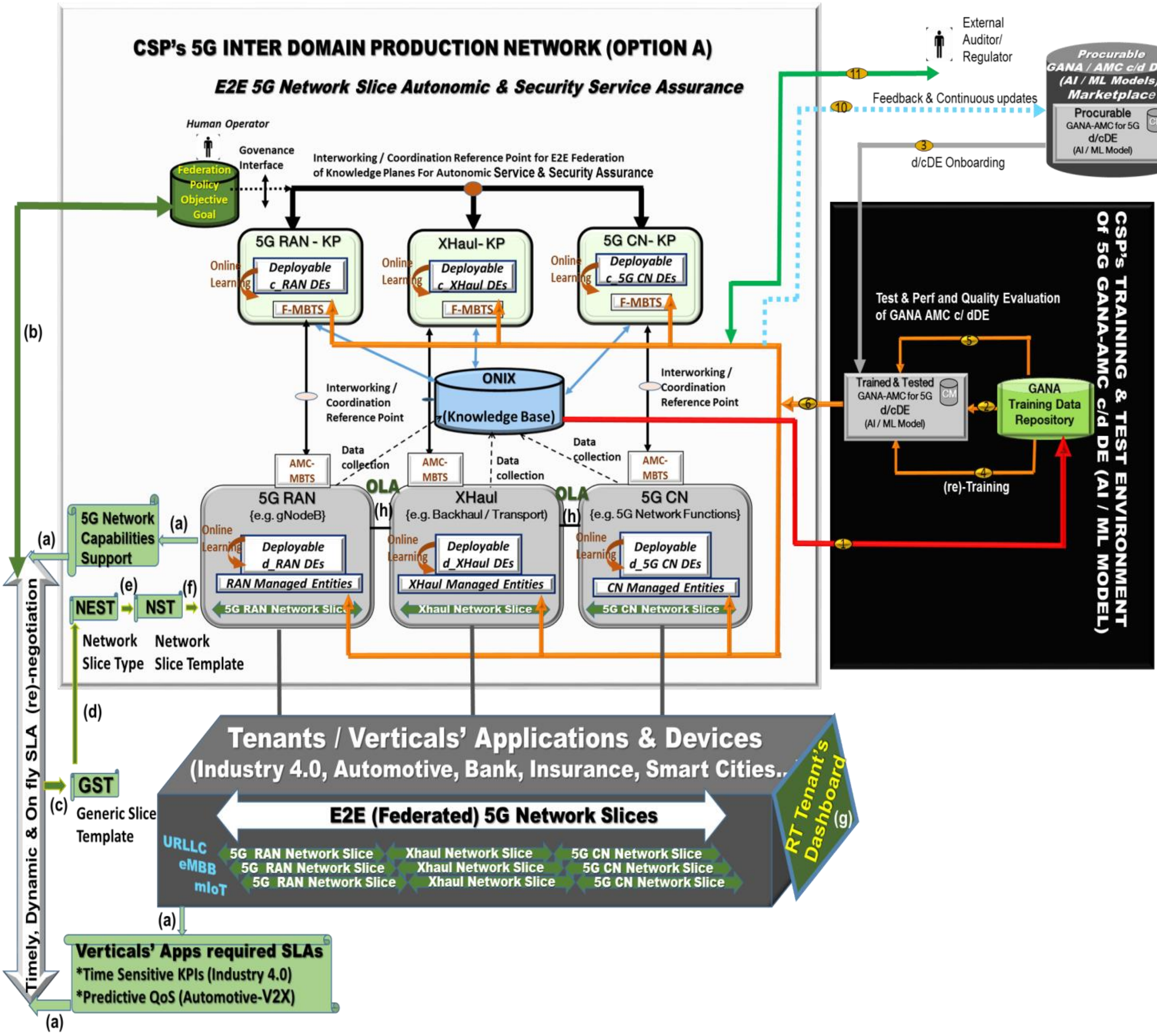

Figure 14: Option-A (Horizontal Federation of Knowledge Planes Platforms) in Inter-Network Segments KP Domains model (within a single Organization Scenario)

7.5.3. Option-B (Hierarchical /Vertical Federation of Knowledge Planes Platforms) in Inter-Network Segment KP Domains model (a single Organization Scenario)

It is the option by which the GANA Knowledge Plane (KP) Platforms for the specific network segments (e.g. 5G RAN, X-Haul, 5G Core Network) federate vertically through an overlay umbrella Hierarchical / Vertical GANA Knowledge Plane (KP) Platform or "Inter-KP Domains Knowledge Plane" that receives information from the lower level KPs (e.g. 5G RAN - KP, X-haul-KP, 5G Core Network-KP) and coordinates the lower level KPs. Figure 15 depicts this option B.

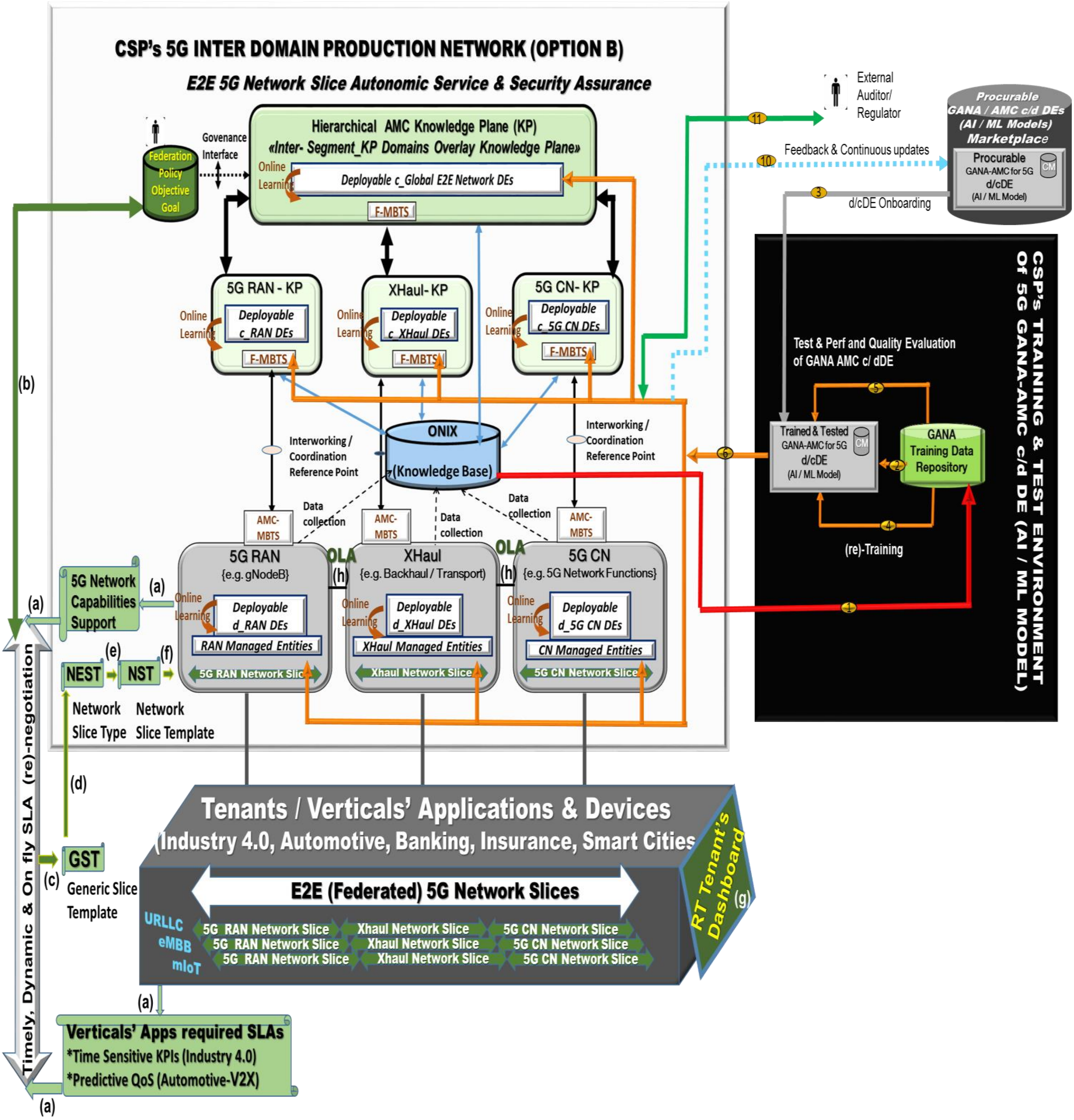

Figure 15: Option-B (Hierarchical /Vertical Federation of KP Platforms) in Inter-KP Domains model (within a single Organization Scenario)

7.5.4. Option-B (Hierarchical /Vertical Federation of Knowledge Planes Platforms) in Inter-Operator model (Multi Organization Scenario)

It is the option by which the GANA Knowledge Plane (KP) Platforms for collaborating Operators' Networks (e.g. Operator #A 5G Network, Operator #B 5G Network, Operator #C 5G Network) federate vertically through an overlay umbrella Hierarchical / Vertical GANA Knowledge Plane (KP) Platform or " Inter-Operator Knowledge Plane" that receives information from the lower level KPs (e.g. Operator #A 5G Network - KP, Operator #B 5G Network - KP, Operator #C 5G Network - KP) and coordinates the lower level KPs. Figure 16 depicts this option B.

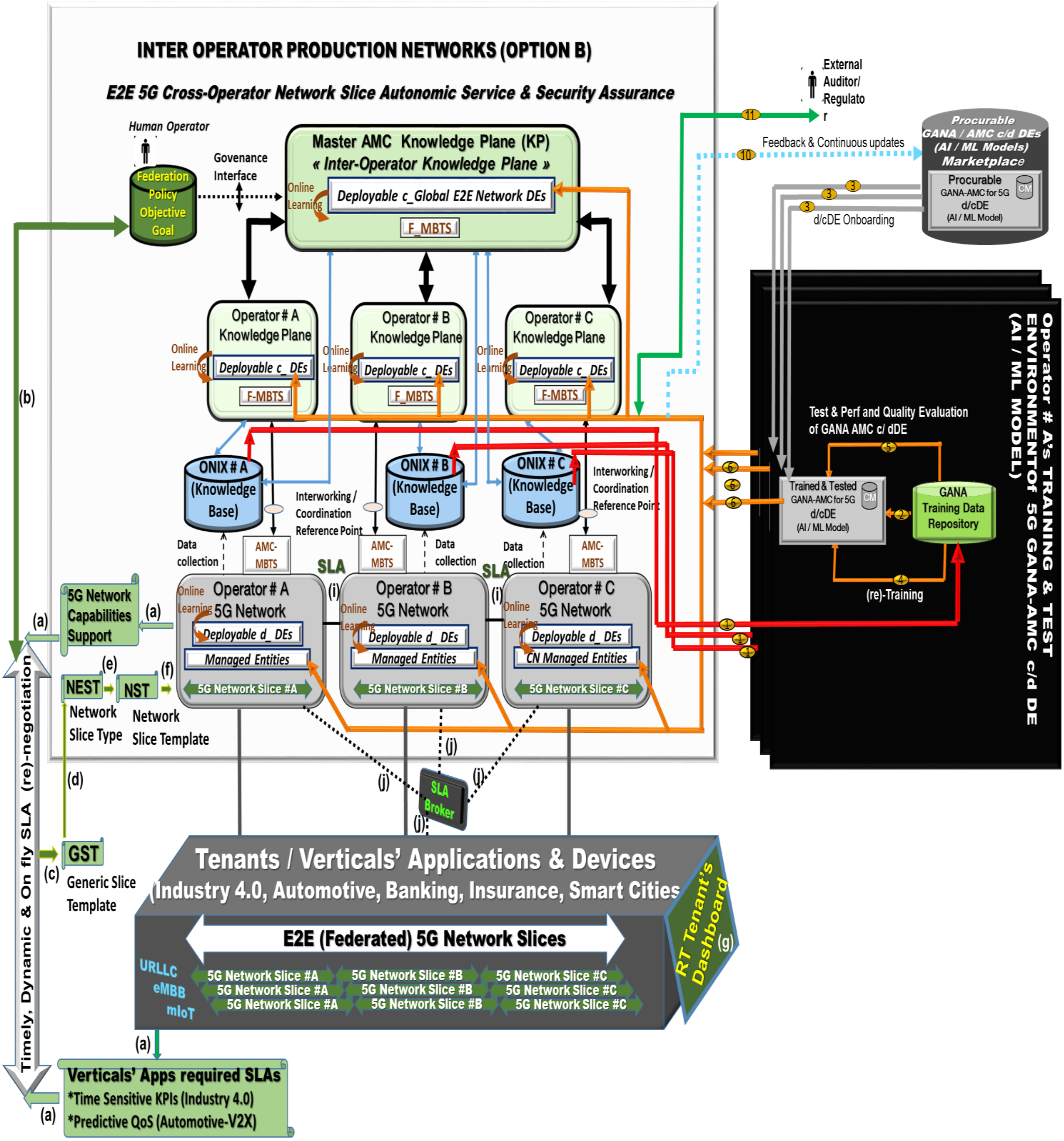

Figure 16: Option-B (Hierarchical /Vertical Federation of Knowledge Planes Platforms) in Inter-Operator KPs federation model (Multi Organization Scenario)

8. Modeling the Interfaces and Primitives/Operations for Enabling Programmability (Manageability) of a Cognitive GANA DE (a Deployable "AI Model" software component for specific AMC targets)

8.1. Overview

The figure below (Figure 17), is an extract of the Model of GANA Decision making Element (DE) as Autonomic Management & Control AI Software Component that has Interfaces and shall support some Primitives on the Interfaces defined in ETSI TS 103 195-2.

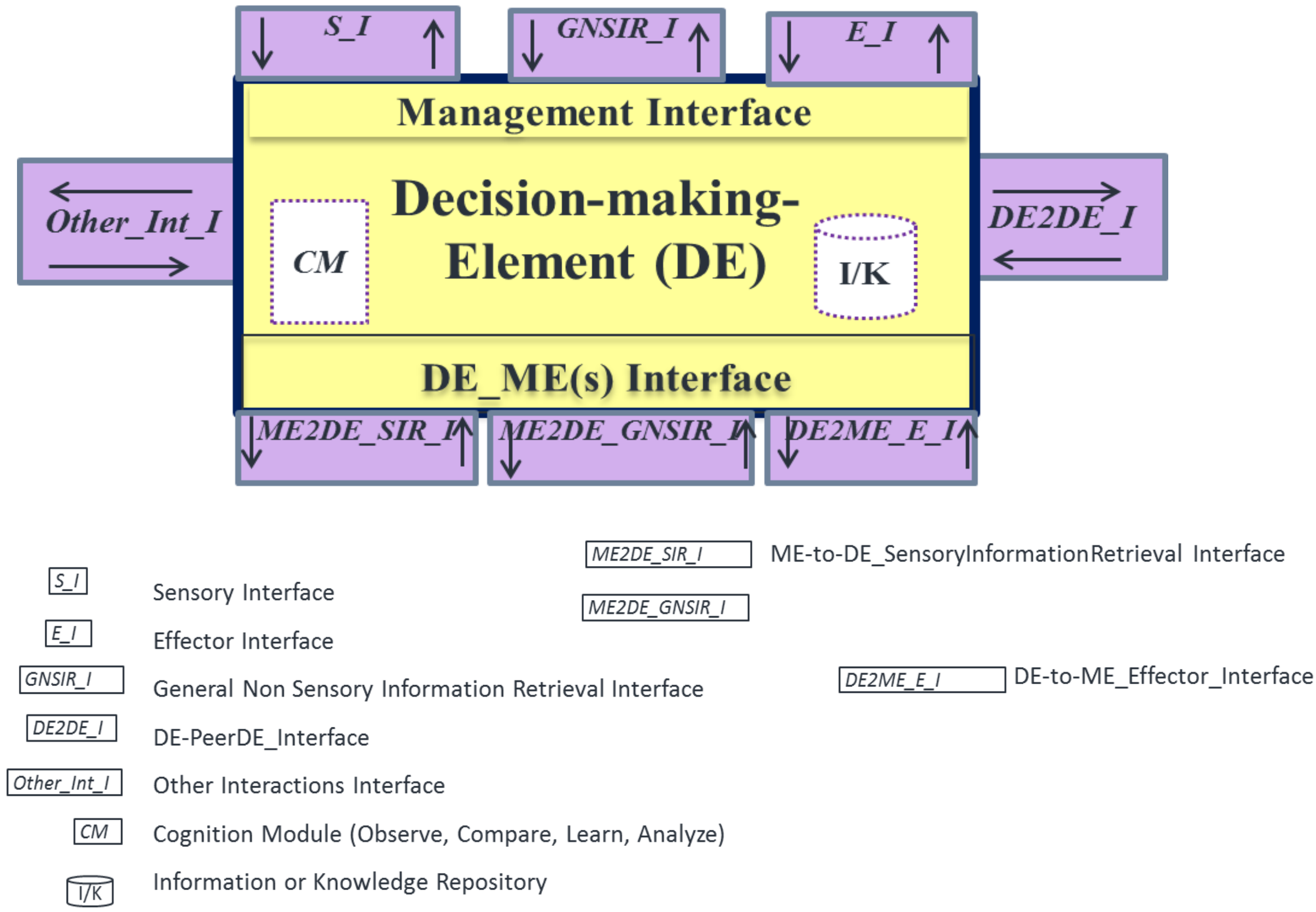

Figure 17: ***Model of a Cognitive GANA DE, and Primitives on the Interfaces Model of a Cognitive GANA DE***

8.2 Primitives/Operations for Enabling Programmability (Manageability) of a Cognitive GANA DE (a Deployable "AI Model" software component for specific AMC targets)

The following figure (Figure 18) illustrates the primitives that can be introduced in extending those already defined in ETSI TS 103 195-2. **NOTE:** These extensions to the primitives are inspired by work in TMForum on AI Models and the Open Digital Architecture (ODA) [6][18].

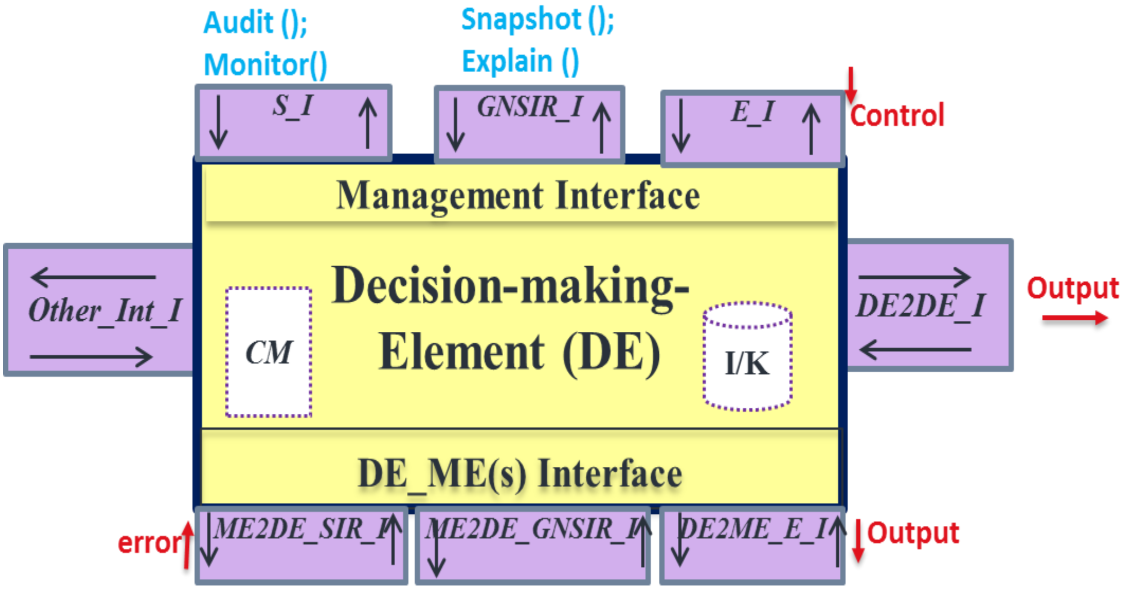

Figure 18: Extending the Primitives on Interfaces *Model of a Cognitive GANA DE defined in ETSI TS 103 195-2*

Descriptions of the Primitives that can be added to those already defined in ETSI TS 103 195-2 for a Cognitive Interface Model:

- The **Audit ()** Primitive should be supported on the **DE's S_I Interface** and can be implemented primarily by the use of the generic **Pull ()** Primitive defined for a DE Model (i.e. **Audit ()** is a **specialized Pull ()** Primitive) as presumed to be supported on this interface. From the DE's perspective, a Pull() is implemented by the DE and an entity that is allowed by a policy can make a call to the specific Pull() operations (e.g. Audit()) to retrieve the information of interest. *[The **Callee** is the DE]*
- **Monitor ()** Primitive should be supported on the **DE's S_I Interface** and can be implemented primarily by the generic **Push ()** Primitive defined for a DE Model (i.e. **Monitor ()** is a **specialized Push ()** Primitive that when called by the DE (as a skeleton, not the actual implementation of the Primitive) it results in a call on the recipient entity to receive the monitoring data/information the DE is „pushing" to the receiver entity that must have been registered as listener entity for the DE to „push" data to. *[The **Callee** is the Receiver Entity of the Monitoring Data].* However, a **Pull ()** Primitive may also be supported in implementing the **Monitor()** Primitive such that any entity (allowed by policy) can invoke(call) a **Pull()** operation on the DE to obtain the intended DE state meant to be always conveyable by **Monitor()** Primitive. When Monitor() is called by an entity (not the DE itself) a Pull() operation is called locally that returns the intended results of the **Monitor ()** call. *[The **Callee** is the DE]*
- **Snapshot()** Primitive should be supported on the **DE's GNSIR_I Interface** and can be implemented primarily by the generic **Get ()** Primitive defined for a DE Model (i.e. **Snapshot ()** is a **specialized Get ()** Primitive). *[The **Callee** is the DE]*
- **Explain ()** Primitive Primitive should be supported on the **DE's GNSIR_I Interface** and can be implemented primarily by the use of the generic **Get ()** Primitive defined for a DE Model (i.e. **Snapshot ()** is a **specialized Get ()** Primitive) as presumed to be supported on this interface. *[The **Callee** is the DE]*

- **data** (as input to the DE) is received or consumed by the DE primarily through either of the following DE Interfaces **DE's ME2DE_SIR_I Interface**; **DE's ME2DE_SIR_I Interface** and various methods of receiving data can be supported by either **Push()** or **Pull()** models supported by the DE and the data source. "data" **is NOT a primitive.**

- **control** is implemented by the Primitives already defined on the **DE's E_I Interface,** such as ***Start()***; ***Enforce_Policy()***; ***Apply_Control_Strategy(), Set(),*** **and the other primitives defined on the DE's E_I Interface.** "control" **is NOT a Primitive.**
- **output** is implemented by the Primitives already defined on the **DE's DE2ME_E_I and DE2DE_I Interfaces primarily,** such as ***Enforce Policy()***; ***De-activate-Policy()***; ***Set()***; ***Test()***; ***Set-Filter()***; ***Apply-Control-Strategy()*, etc. on DE2ME_E_I Interface;** and ***ConveyMessage()*** on **DE2DE_I Interface.** output is communicated mainly as a result of an "*decision*" computed by a DE that results in a "*change request*" by the DE. However, for certain output that requires to be communicated up the DEs Hierarchy, e.g. in escalations of situations the DE is not able to handle but requires the approval to execute certain decisions by its upper DE, the **DE's Other_Int_I Interface or S_I Interface** may be used. "output" **is NOT a Primitive.**
- **Error** is implemented by the Primitive already defined on the **DE's ME2DE_SIR_I,** i.e. the Primitives such as ***Push()*** that can be used by an ME to communicate an *error (or erroneous situation)* to the DE responsible for managing the ME. "error" **is NOT a Primitive.**

Therefore, the additional Primitives that can be added to those already defined on DE Management Interface defined in ETSI TS 103 195-2 are summarized in the Table below.

DE Interface	Sub-interface	Full name of the sub-interface	Caller and Callee/Consumer	Primitives
Management interface	S_I	Sensory Interface	Upper DE as caller of the *Get() and Pull()* primitives and "this" particular DE as callee; Upper DE as callee of the *Push()* primitive and "this" particular DE as caller;	***Get(),*** ***Pull(),*** ***Push()*** **Audit ();** **Monitor()**
	GNSIR_I	General Non Sensory Information Retrieval Interface	Upper DE as caller and "this" particular DE as callee for these primitives	***GetCapabilityDescription();*** ***GetFiniteStateMachine();*** ***GetFaultErrorFailureAlarmCausalityModel();*** ***GetFailureModesDescription();*** ***Snapshot ();*** ***Explain ()***
	E_I	Effector Interface	Upper DE as caller and "this" particular DE as callee	***Start();*** ***Pause();*** ***Resume();*** ***Terminate();*** ***Enforce_Policy();*** ***De_activate_Policy();*** ***Set();*** ***Apply_Control_Strategy()***

9. How the ITU-T ML Framework (ITU-T Y.3172) can be applied in implementing the ETSI GANA Cognitive DEs for Autonomic Management and Control (AMC)

9.1. Overview

The Requirements described in "Recommendation ITU-T Y.3172" are useful for consideration by implementers of the autonomic manager components defined by the ETSI GANA Framework, namely the Decision-making Elements (DEs), while implementing the DEs that need to be instantiated to operate in a specific network architecture (within its Network Elements/Functions(NEs/NFs)) and its associated management and control architecture (in the GANA Knowledge Plane Platform in particular) as guided by a particular GANA instantiation onto the target network architecture and its associated management and control architecture. The ETSI GANA Model is a Hybrid Model that enables innovators of autonomics algorithms (including AI algorithms such as ML and DL algorithms) for GANA DEs to implement and interwork "fast control-loops" in NEs/NFs and "slow control-loops" in the outer realm of management and control systems for a particular network architecture as discussed in [2], [4] and also in ITU-T Y.3324. As described in [2][4], the ETSI GANA Model is a Hybrid Model for realizing the AMC paradigm and is very much compatible with and embraces the Hybrid SON (Self-Organizing Network) Model (consisting of Distributed-SON and Centralized-SON complementing each other and made to interwork together by way of C-SON policy-controlling D-SON). Though the GANA Model applies not only to AMC for RAN (Radio Access Network) but is a generic model that can be applied to other network segments such as X-Haul Transport and Core Network as illustrated in various GANA instantiations onto target architectures such as GANA in BBF architecture scenarios (ETSI TR 103 473 V1.1.2) and GANA in 3GPP Backhaul and EPC Core Network (ETSI TR 103 404). The ITU-T Y.3324 also provides insights on the AMC paradigm in IMT-2020 and how to use the ETSI GANA Model to realize AMC in IMT-2020. The broader scope of AI (Artificial Intelligence) in ETSI GANA Model includes ML, DL and computational intelligence algorithms that can be applied in designing and implementing DE logics at GANA Levels 2 and 3 (i.e. levels of autonomic control-loops implemented within a Network Element/Function (NE/NF) of a network architecture, and GANA Level-4 (known as the GANA Knowledge Plane (KP) level). The GANA DEs of relevance to consider in applying the framework proposed in ITU-T Recommendation Y.3172 are Cognitive DEs designed to operate at GANA Level-2, Level-3 and Level-4 (Knowledge Plane DEs). Benefits of having of the realization of "fast control-loops" by DEs injected into certain NEs/NFs and complementing them with "slow control-loops" realized by Knowledge Plane level DEs are described in [4] and in ETSI TS 103 195-2. In some cases, the intelligence that lower level DEs injected into certain NEs/NFs (i.e. "*in-NE/NF AI*") can bring, apart from realizing certain self-management operations that can be delegated to an NE/NF or realizing some "fast control-loops" for certain aspects that require fast local reaction by the NE/NF, is that, such local intelligence can limit or reduce the amount of telemetry data that needs to be exported directly from NEs/NFs to external data collectors. This can help reduce the overloading of the NEs/NFs with collecting and exporting huge data. Even though still certain telemetry data of limited volume could still be exported by NEs/NFs to central Data Collectors (Data Lakes) that feed data or synthesized knowledge (by AI algorithms running on the Collectors) into the Knowledge Plane Platform, provided that such data helps build knowledge required by the Knowledge Plane Platform for its closed-loop autonomic operations. Lower level DEs injected to operate in NEs/NFs export aggregate reports to the Knowledge Plane Level DEs and dynamically receive policies from the KP level DEs to apply locally.

9.2. Mapping the Concepts in ITU-T Recommendation Y.3172 to the ETSI GANA Framework to provide guidance to implementers of GANA Cognitive DEs on how the ITU-T Framework can be applied

The following mappings can help implementers of Cognitive DEs designed to operate at GANA Level-2, Level-3 and Level-4 (Knowledge Plane DEs):

- A Cognitive GANA DE (at GANA Levels 2,3 or 4) must be treated as a node (in terms of the ITU-T Framework (ITU-T Recommendation Y.3172)), a special node that constitutes a Deployable ML Model (M). **NOTE:** The concept of cognitive DE is defined in ETSI TS 103 195-2
- According to the ETSI GANA Framework, which allows for flexibility to combine and interwork "fast control-loops" DEs injected into NEs/NFs and "slow control-loops" DEs outside of NEs/NFs, ML Pipelines and their associated nodes (Source of Data (SRC)), Collector of data (C), Data Pre-processing (PP), Deployable Model (M), Policy (P), Distributor (D), and SINK) can be applied at two layers, namely NEs/NFs layer and the collective outer layer of the GANA Knowledge Plane and its interworking with other management and control systems such as OSS, SDN Controllers, Orchestrators, etc. (i.e. the GANA's abstraction layers for self-management functionalities as captured in ETSI TS 103 195-2) .
- A GANA DE (both, a cognitive DE or a non-cognitive DE) can act as an SRC for other DEs (Deployable Models (Ms)) that can be chained in an ML Pipeline to realize an AMC objective involving the collaboration of multiple DEs
- A GANA DE (both, a cognitive DE or a non-cognitive DE) acts as a SINK for its associated upper DE (Deployable Models (Ms)) in an AMC objective
- A higher level DE (along the GANA Decision-making Hierarchy) that is assigned to policy control its lower level DEs or Managed Entities (MEs) it owns (ETSI TS 103 195-2 defines the ownership

relationships among DEs) views its lower DE(s) or ME(s) as a SINKs (and a SINK is always downstream relative to the upper DE issuing commands). The Network-Level *AutoDiscovery_&_AutoConfiguration-DE* (also called *AutoConfiguration_&_AutoDiscovery-DE*) in the GANA Knowledge Plane (KP) views DEs in the Knowledge Plane as its SINKs and also its "mirror" AutoDiscovery_&_AutoConfiguration-DE injected to operate in a NE/NF as its SINK for its outputs, accordingly.

- The *Network-Level AutoDiscovery_&_AutoConfiguration-DE* of the GANA Knowledge Plane (KP) should be the entity that fulfils the role of a MLFO (ETSI TS 103 195-2 provides more details on how this particular DE and the KP DEs must handle *intent* (also as described earlier), while the *AutoDiscovery_&_AutoConfiguration-DE* could act as an orchestrator of the other DEs and DE chaining and at the same time perform coordination of the operations of the other DEs as described in ETSI TS 103 195-2 and 5G PoC White Papers No.1, No.2 and No.3 available at https://intwiki.etsi.org/index.php?title=Accepted_PoC_proposals). As described earlier in section 6.4, the Security-Management-DE is to be involved in the process of intent inputs handling by the *AutoDiscovery_&_AutoConfiguration-DE* and in what it does in enabling DEs coordination, DEs interactions compositions and chaining, as the Security-Management-DE should determine and enforce security in the various communications between DEs.
- Collector of data (C) needs to be implemented both within an NE/NF scope and the outer scope (in the space accessible by the GANA Knowledge Plane(s) or within the Knowledge Plane(s)—as some data collectors may be implemented as an integral part of a Knowledge Plane implementation). A local Collector serves its purpose for ML Pipeline(s) instantiated within an NE/NF to realize "fast reactions" by GANA Level-2 DEs and/or GANA Level-3 DEs in their realization of fast control-loops in an NE/NF, or for the reason that a distributed autonomics algorithm may have been desirably implemented by making DEs within certain NEs/NFs collaborate by themselves within the network infrastructure than being implemented as a centralized algorithm. A Collector implemented outside NEs/NFs serves its purpose in ML Pipelines instantiated for Knowledge Plane DEs to take part in delivering a collective AMC objective
- Within an NE/NF a D (distributor) node can be implemented as an API identified in the ETSI GANA Node Model as "***Rfp_GANA-Level2&3-AccessToProtocolsAndMechanisms***" described in ETSI TS 103 195-2. D (distributor) node meant to serve ML Pipelines outside of NEs/NFs may be implemented as a publish/subscribe function.
- According to the ETSI GANA Framework a Data Analytics Module can be implemented as a shared module among DEs (among GANA Level-2 DEs, among Level-3 DEs, or among Level-4 DEs) or a Data Analytics Module may be implemented as an integral part of a DE. That implies that a Data Pre-processing (PP) Node may be an implementation of a Data Analytics Module, or the Data Pre-processing (PP) Node may be considered as embedded within a DE as a Deployable ML Model (M).
- According to the ETSI GANA Framework Cognitive DEs employ various types of AI algorithms (not just ML algorithms) and a Cognitive DE emits to its SINK (called its Managed Entity (ME)) commands or policies (in upper DE and lower-DE relationships) as it dynamically computes plan of actions and policies to apply and effect a change on the behaviour or state of its target ME(s). For actions or policies that are output by a Cognitive DE (as a Deployable ML Model (M)) that can be directly executed without the need for coordination by the coordinator DE (*AutoDiscovery_&_AutoConfiguration-DE*) first, then the Cognitive DE's output is to be sent to the target SINK directly, while for actions or policies outputs by the Cognitive DE that must be sent to the coordinator DE for coordination first before they are sent to the target SINK the AutoDiscovery_&_AutoConfiguration-DE plays the role of the Policy node that receives the Cognitive DE's output. NOTE: There may be certain DE outputs that are communicated to another DE(s) for the realization of an AMC objective that must be achieved through the collaboration of multiple DEs.
- As described earlier, the ETSI GANA Model (ETSI TS 103 195-2) defines Interfaces and primitives that should be supported on DE interfaces and such interfaces and primitives should also be considered when designing ML Pipelines
- The ETSI GANA Model (ETSI TS 103 195-2) defines the Model Based Translation Service (MBTS) Function that can be employed, e.g. between the Knowledge Plane and NEs/NFs of the network

infrastructure, and such an MBTS Function should also be considered when designing ML Pipelines in the outer realm of NEs/NFs

10. GANA Cross-Layer Autonomic & Cognitive Business-Service-Network Framework and the Benefits and Value Creation the Framework brings, and AMC/Self-Management Use Cases Description Template

10.1. GANA AMC Requirements Framework(Template) for Capturing the Capabilities required of an Autonomic/Cognitive Business-Service-Network

This framework illustrates the evolution of today's Business-Service-Network management in order for a network and services management framework to become intelligent, open, flexible, autonomic and autonomous in as far as automating tasks that would otherwise involve manual intervention by humans, secure, context-aware, policy-based, business-driven and SLA-driven. It is structured through the following four types of requirements from a network operator perspective:

- *Strategic Requirements*
- *Governance Requirements*
- *Operational Requirements*
- *Autonomous "network and services management" behavior and Cognition Requirements*

In order to better understand the Requirements, the requirements are mapped onto the typical high level operator's network with respect to the layering model of a "Business-Service –Network" as illustrated on Figure 19.

10.1.1 Strategic Requirements

This type of requirements is focusing on business intelligence and associated partnerships necessary to implement a strategy associated with the following measurable KPIs and associated targets:

- *Minimize OPEX/CAPEX*
- *Maximize user satisfaction*
- *Minimize carbon footprint*
- *Maximize revenues*

In this context, the Framework illustrates this partnership from stakeholders and partners' viewpoint by a high level (abstraction) layered architecture composed of two main domains, Network Operator's domain and Vendors' domain.
Figure 19 depicts the network operator's domain, which consists of the following:
Two upper layers at the top:

- *Business Policy,*
- *Service Objective,*

Three lower layers at the bottom:

- *Network Operator's OSS*
- *Network and its associated legacy management systems (EMSs, NMSs). ETSI MANO and SDN Controllers could be part of this layer for NFV/SDN part of the Network.*

10.1.2 Governance Requirements

For the purpose of network governance, an interface is needed to allow the operator to instantiate or adjust the features of the demanded service/infrastructure. This is the reason why a business level language is required to help the operator to express what it is needed from the network. Such a business language shall be semantics-oriented and may be modelled by the use of ontology to add semantics and enable machine reasoning on the goals.

Indeed, Network Operators and Services Providers are expecting benefits and usability of ontologies in their service strategies within highly competitive and fast moving market environment with strong Time-To-Market constraints. Ontologies capture the semantics of information from various sources and are a powerful tool in services design, service composition (service logic) and service personalization through specific user profiles in a dynamic way. At the same time, current object-oriented information models are less flexible to meet this objective. This requirement has a direct impact on existing BSS/OSS information models.

Such a Business Policy level description language eases the automation of "Edition - Translation - Execution" of Policies. This leads to the translation into "Service Profiles" at Service level and into "Network Profiles" at Network level.

Finally, after translation phase, the distribution process of Service Profiles and Network Profiles is performed in order to prepare the execution and enforcement. The last phase of this process is the "Policy and Rule Enforcement and Execution" by the Network Elements/Functions (NEs/NFs) in the vendor's domain as depicted in Figure 19.

This approach for network governance gives the network operator a mechanism for controlling the network.

10.1.3 Operational Requirements

This type of requirements aims at improving operation efficiency (reduce OPEX). One way to achieve this goal is to harmonize Business Support System (BSS) and Operation Support System (OSS), Data Models and to deploy a standardized northbound management interface. Such a harmonization is vital in the context of converged Fixed-Mobile network and services management. With the advent of NFV, the integration of Service Fulfilment and Service Assurance through shared real-time inventories also helps in the target of OPEX reduction.

From management architecture perspective, Figure 19 maps these "Operational requirements" to the real Network Operator's architecture that handles the implementation. The network environment (Vendors' domain in the Figure 19) should be managed by the business objective input which will drive the service objective. The service objective should then be translated into policy rules which shall be enforced in the operator's network through the operator's Network Management System (NMS). The policy enforcement should then be executed by the vendor's Element Management System (EMS) and the Network Elements/Function (NE/NF) forming the operator's network. Each layer of the whole architecture has to take into account its intrinsic constraints.

10.1.4 Autonomous "network and services management" behavior and Cognition Requirements

This type of requirements aims at taking advantage of introducing Self-Awareness, Analyzing, Learning, and Reasoning capabilities and mechanisms. It also includes gathering information, transforming it into knowledge and distributing it to various entities that need the knowledge (e.g. in decision-making). There is also a need for building and ensuring Trust and Confidence as well as Stability in Autonomics Control-Loops for the network as described in ETSI TS 103 195-2.

From management architecture perspective, Figure 19 maps these "Autonomous network and services management behavior and Cognition Requirements " to the real management architecture.

The cognition aspect is shown by "cognition module" (purple boxes) in the right part of the Figure 19. These cognition modules are used to retrieve relevant knowledge from data/information and it enables and allows for the cross-control loop interactions accordingly. These cognition modules can also be seen as "brokers" where various knowledge sources store the knowledge in a controlled and secured way, while, the users of these knowledge retrieve required and relevant knowledge through a subscription model. In this context, a dissemination plane is used to disseminate knowledge and decision.

NOTE: The indicated Cognition Modules can all be implemented within the GANA Knowledge Plane's DEs or can be shared among Knowledge Plane DEs as described in ETSI TS 103 195-2.

The Autonomicity capabilities are introduced in this management architecture thanks to Autonomic Functions (AF) (pink boxes) which include the Decision Making Element (DME or DE—in short) at different layers (Business-Service_Network). This implementation of these AFs in the autonomic network architecture is to be driven by operator's policy of network and service operations, as summarized below:

- Distributed manner (*fast control-loop(s)*): the AFs are embedded in the NE/ NF only
- EMS-Centralized manner (*control-loop(s) slower than the fast control-loop(s) implemented at NE/NF level*): the AFs are embedded in the legacy EMSs
- NMS-Centralized manner (*control-loop(s) slower than a control-loop(s) implemented at EMS level*): the AFs are embedded in the operators' legacy OSS

NOTE: Control-Loops implemented at the Knowledge Plane level are slower than the control-loops that may be implemented at NMS, EMS and NE/NF levels, as the Knowledge Plane is expected to view the lower levels as data sources (e.g. event sources) and also policy control any lower level control-loops introduced at the lower levels as described in [5][17] [19] [21].

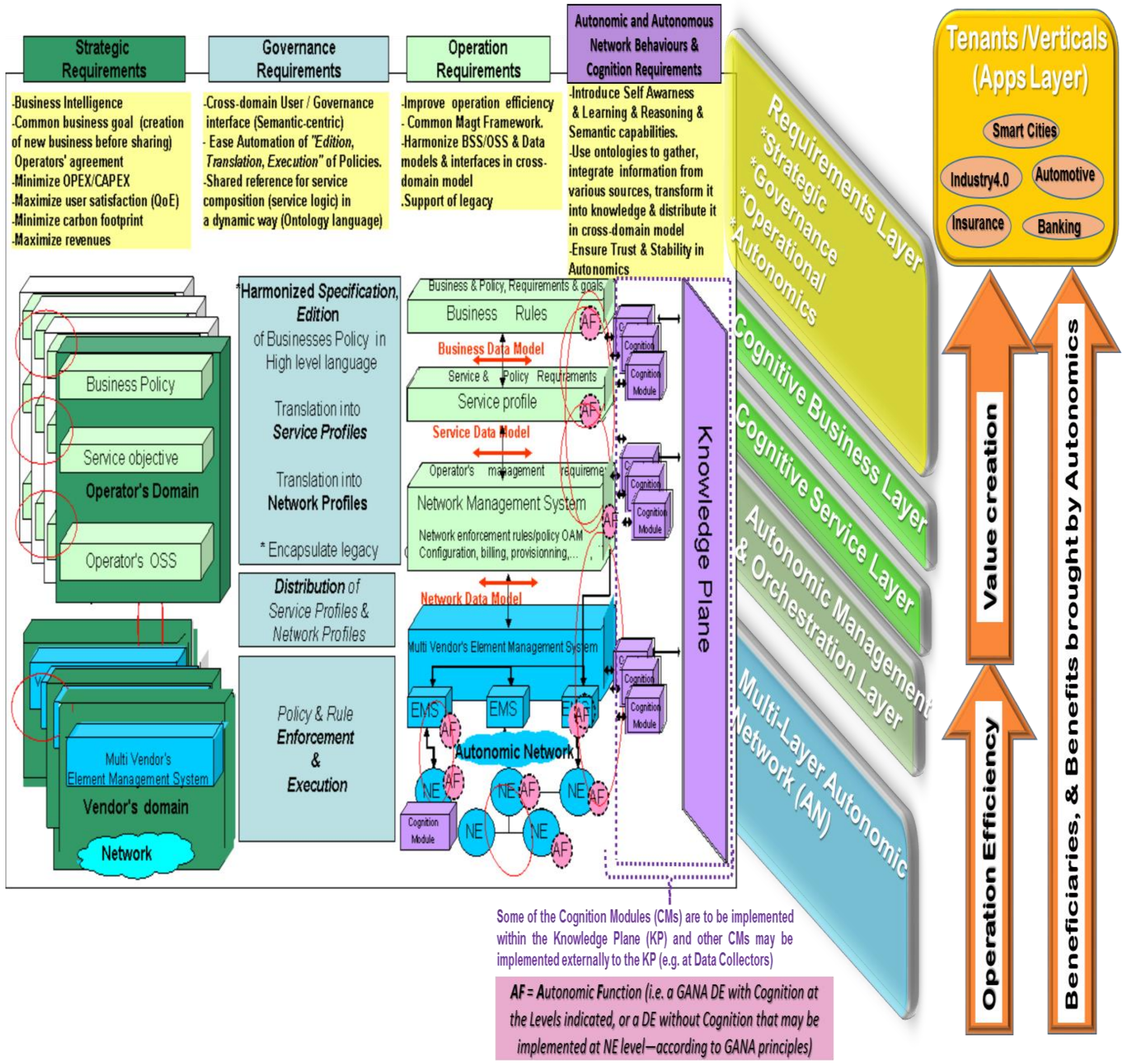

Figure 19: Requirements Framework for a Policy- based management of a GANA Multi-layer and Cross-layer Autonomics Business-Service –Network (ETSI TS 103 194)

10.2. Use Cases illustrating GANA-enabled Autonomic & Cognitive Business-Service-Network Framework

ETSI TS 103 404 documented a large number of AMC Use Cases proposed according to a Tabular Use Case Description Template structured into the following fields:

- *Description, Story/Use Case*

- *Network Environment (e.g. indicating the type of the considered network segment(s) e.g. Home Network, Access Network, Edge Network, Private Network, Core Network, or other network types)*
- *Problem statement*
- *Function impacted*
- *Systems involved*
- *Indicators/ Evaluation criteria/ Metrics to measure the value of automated management and autonomics*
- *Players that must be involved in the realization of the Use Case*
- *Beneficiaries and the Benefits brought by Automated Management and Autonomic Management and Control (AMC)/Autonomics*

To illustrate the GANA Cross-Layer Autonomic & Cognitive Business-Service-Network Framework, and the Benefits and Value Creation the Framework brings, as well as the GANA AMC Requirements Framework(Template) for Capturing the Capabilities required of an Autonomic/Cognitive Business-Service-Network, this section presents the following selected four Use Cases:

- ***Autonomics in legacy network scenario***
- ***Self-Management of Coverage and Capacity in Wireless Systems***
- ***Cognitive event management (Fault/Anomaly/Intrusion Detection) and Resolution by Root-Cause Analysis (RCA) and Autonomic (Closed-Loop) Self-Healing/Remediation)***
- ***Autonomic Network Monitoring using an ad-hoc overlay network***

1) Autonomics in legacy network scenario

Table 1: Autonomics in legacy network scenario: ETSI TS 103 194

Title	Autonomics in legacy network
Description/Story Use Case	The legacy network is composed of a panel of players which need to cooperate in order to provide user services with associated QoS and security as prerequisite for launching a service. The number of equipment and players is continuously increasing in order to cope with the development of new services and to satisfy new demands/customers, while the manageability of this legacy infrastructure and cooperation among these players is reaching the limits of human capacity. Adding new service needs is challenging. Indeed, more and more strong cooperation between all the players, even the user, is required in order to provide these new services. This multilateral cooperation is handled manually without automatic process, because of the case by case manner needed to address the particular constraints of each player. Information exchange provides the context, of the user, network and service The Service Provider is expecting a service delivery through a ubiquitous infrastructure as well as a transparent management through this multi-player infrastructure, such as programmable overlays of virtualised resources (communication, processing, storage, etc.). The major shift here is the dynamic provisioning whatever the underlying physical resources. Users are not techno aware. They just want plug and play services with no configuration and they want to select/use services existing in the marketplace] (in reference to NGMN document "A Requirement Specification by the NGMN Alliance NGMN Recommendation on SON and O&M Requirements, NGMN alliance, (2008)") [27].
Network Environment(s)	All
Problems	**Current Management practices:** Within the current network management practices, a network administrator needs to manually interact with infrastructure and players. Incoherence in the management could happen between the different agreements: Services interactions conflict are manually resolved Equipment shall be manually configured by users/administrators in order to connect to the infrastructure. Infrastructure is not updatable, optimisable, etc. End to end management needs the involvement of numerous experts at each level of the operation organisation (vertical layers and horizontal domains) because monitoring information is provided with no coherence and no consistency. Detecting congestion or adapt the performance of a node is difficult to realise between players. Seamless continuity of services is difficult to deliver, because services are statistically configured for a type of access network and for a set of users. Service continuity needs to analyse the user environment in real time (whatever the state of network) in order to reconfigure the network and provide adaptable services continuity.
Functions Impacted by the need for automated management and AMC	Management, control, transport, Applications
Systems Involved	Management system; Control system; Media transport system

Title	Autonomics in legacy network
Indicators / Evaluation criteria / Metrics to measure the value of automated management and autonomics	**Zero configuration** for users' equipment connected to the Home area network with IP connectivity through Self configuration mechanisms **SLA agreements** for commercial services and universal services shall be met within multi-player environment thanks to network interoperability and monitoring mechanisms. These mechanisms shall be able to identify responsibilities of each player in case of degradation or deviation from the SLA agreement. It can be achieved through Self-monitoring mechanisms. **Level of human involvement in the network management**: A control plane and the management plane shall orchestrate self-optimisation of different resources (nodes, virtualised nodes, overlay functions, last mile, etc.) of the network belonging to different players with coherence, consistency, security in order to provide service continuity adapted to user environment with less human intervention under confidence and trust conditions. It can be achieved through Self organising mechanisms. **Improvement of processes**: delivery time, level of security quality and automatic resolution of alarms reported with less human intervention. These 4 indicators need a decision provided in global coherence with situated and appropriate view. Indeed, information exchanged between players should provide knowledge with guarantee of security, integrity, privacy and the information should be described using a common language. This knowledge shall be adaptable, up to date, consistent, etc.
Players	Network operator
Beneficiaries, and the Benefits brought by Automated Management and Autonomics	**Operator:** Reduction of OPEX by minimizing the time and effort needed for managing network devices by the network management personnel (i.e. administrators). **Manufacturer:** by updating existing products and developing and selling new product lines embedding new and advanced features for automated management and autonomic management **Users and other players**: could use plug and play infrastructure

2) Self-Management of Coverage and Capacity in Wireless Systems

Table 2: Self-Management of Coverage and Capacity in Wireless Systems: ETSI TS 103 194

Title	Self-Management of Coverage and Capacity in Wireless Systems
Description/Story Use Case	In a wireless infrastructure, network management and, in particular network planning, becomes a challenging task because of the volatile and unpredictable nature of the wireless medium and the mobility patterns of terminal devices. Due to the strong demand for efficient wireless resources utilization, wireless network planning and management is a sophisticated task, which, more often than not, requires expert knowledge, especially in a dense urban environment. In cases where homogeneous and heterogeneous wireless networks operating under different administrations reside in the same geographical area, the complex problem of efficient wireless resource management arises, under several constraints. Network nodes (i.e. access points) that have several configuration capabilities and observe their local operational status should coordinate for network management. A centralized approach is not effective due to scalability and complexity issues. Thus, a more localised and distributed architecture is necessary for the orchestration of various heterogeneous or homogenous access points (APs) or base stations (BSs). This use case presents the steps taken by self-manageable APs or BSs in a wireless network: a) to make deductions about its operational status b) to proactively react to internal/external triggers and c) implement the necessary actions based on its decision mechanism, thus seizing the need for human intervention.
Network Environment(s)	Wireless Access Network
Problems	Autonomic and localised management of variable capacity and coverage requirements as well as of the configuration actions for the identified symptoms in the wireless medium e.g. high load, interference. Some, management problems that need to be addressed: a) Efficient channel allocation among homogeneous Radio access technologies (RATS (e.g. IEEE 802.11) by making better use of the channel allocation conflicts, b) Activation or de-activation of access points/base stations (e.g. IEEE 802.11) assessing the specific characteristics of the specific network area, c) Base stations-assisted user equipment handover (vertical, horizontal)

Title	Self-Management of Coverage and Capacity in Wireless Systems
Functions Impacted by the need for automated management and AMC	The following autonomic management functionalities are provided: • Self-optimisation of APs/BSs capacity and coverage features during their operational state in order to proactively and autonomously configure them according to local and global requirements. • Self-configuration of APs/BSs in the context of their pre-operational state and autonomous selection of execution options during their operational state. • Self-organisation: In a distributed and collaborative way the network nodes (APs/BSs) decide the optimal formations according to their knowledge models and policy rules/SLAs that are locally stored and updated or provided by the respective network operators. • Self-awareness: Access points by sensing the wireless medium and communicating with neighbouring network nodes exchange knowledge data, KPIs as well as policy rules in order to develop their situation awareness for the next nodes. User devices are also used as monitoring points from the respective APs/BSs.
Systems Involved	Wireless access points or base stations as well as user devices (e.g. mobile devices) are the main systems of this use case
Indicators / Evaluation criteria / Metrics to measure the value of automated management and autonomics	• Measure wireless resources (or capacity) usage improvement (cells load, cell throughput) juxtaposed with communicational or computational load (e.g. transmission overhead) due to the introduced mechanisms. • Pattern recognition and knowledge extraction processes will be evaluated with respect to their classification ability, i.e. how well they can identify a problematic situation and its corresponding solution. • The applicability of the dynamic combination of rules will be evaluated with respect to the computational resources it will require and compared against the baseline approach (application of static rules) • Optimise the induced solutions and minimise delay.
Players	**Network Operator** **Manufacturer** **End user**
Beneficiaries, and Benefits brought by Automated Management and Autonomics	**Network Operator:** will minimize the cost related to network management and maintenance (OPEX), while having the ability to identify optimisation opportunities and handle proactively alarms. More efficient usage of the available resources means less energy cost and better Quality of Service **Manufacturer:** will develop and update the software for self-manageable APs/BSs. Improved product portfolio with optimised performance status. **End user:** will be benefited by receiving better QoS features as well as fewer disruptions.

3) Cognitive event management (Fault/Anomaly/Intrusion Detection, Resolution by Root-Cause Analysis (RCA) and Autonomic (Closed-Loop) Self-Healing/Remediation)

Table 3: Cognitive event management (Fault/Anomaly/Intrusion Detection): ETSI TS 103 194

Title	**Cognitive event management (Fault/Anomaly/Intrusion Detection, Resolution by Root-Cause Analysis (RCA) and Autonomic (Closed-Loop) Self-Healing/Remediation)**
Description/Story Use Case	Advances in telecommunication networks have fuelled the rapid growth of new services. User mobility has become an important factor in the quality of service provision for every network operator. Current network management requires specific human intervention to oversee network behavior and ensure that they deliver services requested. Every day running tasks include the ongoing detection of unusual or undesirable behaviors in order to address issues like fault diagnosis and problem resolution. The achievement of these goals is extremely difficult in distributed wireless environments where it is necessary to correlate information from different network levels and network elements. Typical problems like anomaly detection, fault prediction or intrusion detection can be addressed through the identification of unusual behaviors (thanks to autonomics). The idea is based on the fact that the occurrence of faults notification and alarms should follow patterns, which, upon recognition, can be used to predict the fault's occurrence. The last one ensures the remedial actions that can be taken by autonomics beforehand in order to achieve the system functioning without interruptions. The above processes should be automated by an autonomic network and human intervention should be minimised, thus providing a viable solution for self-healing in wireless networks. Thus, when an anomaly is discovered, the involved network elements can use alternative settings of profiles or configurations. The scenario is realised in the following specific steps: 1) Continuous monitoring of selected features in the prediction model will provide at each given time a view of the element's internal functions as well as its environment. This information will serve as the current situation input to the fault prediction model (a model which is able to proactively detect fault and instability in the network, this model could learn on the fault which could happen according to the prediction model. 2) Monitoring data is classified into three categories based on the source: network sources, system sources and application sources (e.g. IP packets, syslogs, application logs, MIBs). 3) Appropriate mechanisms take part to associate the current situation with the patterns recognised and depicted in the prediction model. 4) In case the association results point to an imminent fault or anomaly, preventive measures are undertaken and selected by a pool, where symptoms and measures are paired. The measures might point to an alternative configuration, traffic rerouting, load balancing, node isolation, etc. 5) An autonomics feedback loop with the knowledge base is also envisaged to update and improve the prediction model on a regular basis. 6) Moreover, artificial intelligence methods (e.g. unsupervised) will contribute to the training process by identified unknown alarms or attacks. This enables the cognitive capability of detecting previously "unseen" attacks or faults. This enables the network to assess the threat earlier than traditional mechanisms. 7) In addition, the decision mechanisms ensure that an event based on monitoring data and existing knowledge can be characterized as an alert or possible alert. 8) In execution step, the actual reconfiguration takes place. Parameters are tweaked or alternative preventive measures are taken in order to avoid the imminent fault or attack. 9) The execution process is realized in activation of planned processes or information dissemination about the current status of intrusion detection or anomaly detection to other nodes or the autonomic management systems.
Network Environment(s)	Wireless access Environment

Title	**Cognitive event management (Fault/Anomaly/Intrusion Detection, Resolution by Root-Cause Analysis (RCA) and Autonomic (Closed-Loop) Self-Healing/Remediation)**
Problems	The dynamic wireless networking environment and the mobility of the devices give rise to problems that increase the network management complexity. The emergence of some problems can affect a much larger number of users and services. Therefore, the cognitive event management can improve current network management procedures, and some problems that will be addressed include: • Anomaly detection, as the realization of unusual or undesirable situations. For example, detection of the nature of traffic anomalies in a wireless network is a vital problem to consider, because of the volatile and unpredictable nature of the wireless medium and the resource constraints of mobile devices. Available TCP mechanisms cannot discern timeouts caused by short scale fluctuations in the wireless medium status from delays due to congestion or any other cause e.g. environmental factors, interference. Usually, traffic anomalies can create congestion in the wireless links and stress resource utilization, which makes early detection crucial from an operational standpoint. Of course, a non-detectable anomaly event at one network level could be easy to detect using monitoring data from different networking levels. In a real distributed environment, the challenge point is the collection of appropriate statistics at the local level and the pool of these at the regional level to detect these patterns following a bi-directional reasoning. Moreover, the task of anomaly detection can be useful for fault isolation and identification. • Another problem that can be addressed is the enhancement of the existing intrusion detection mechanisms. Most current network "intrusion detection systems" (IDS) make use of techniques which rely on labelled training data (e.g. data mining-based or signature-based). This approach has shortcomings, such as the expensive production of training data or the difficulty in detecting new types of attacks. Moreover, the cognitive mechanisms of anomaly detection, which rely on unsupervised methods, can help the network be trained with unlabelled data. This enables the cognitive capability of detecting previously "unseen" attacks. In this way, the network assesses the threat earlier than traditional IDS mechanisms.
Functions Impacted by the need for automated management and AMC	The self-awareness autonomic functionalities are provided to facilitate self-protection and self-healing: • self-awareness, as continuous knowledge building process to assess operational status and finding of patterns • self-protection, proactively compensating/overcoming foreseen events • self-healing, reactively responding to unplanned events (e.g. failures) and providing corrective actions
Systems Involved	Wireless Access Points, Routes, Firewalls, IDS
Indicators / Evaluation criteria / Metrics to measure the value of automated management and autonomics	• Precision (as the ratio of correctly identified failures to the number of all predicted failures). This ratio refers to the number of true positives prediction to the total number of predicted positives analysed by the prediction model, against the detection rate which are predicted, i.e. the proportion of total true anomalies that are detected • Recall (as the ratio of correctly predicted failures to the number of true failures) • Precision/Recall-Curve (as mechanism to precision over recall for various threshold levels • In case of statistical approaches, the performance of the statistical algorithms can be expressed in terms of the prediction time and the mean time between false alarms
Players	• End user • Network operator • Manufacturer • Service Provider
Beneficiaries and the Benefits brought by Automated Management and Autonomics	**End user:** satisfied users (enjoy better services), thus they assess positively the network and services **Network Operator:** reducing human intervention **Manufacturer:** feedback from specific network management events may lead to better product development **Service Provider:** convergence to achieve the desired QoS

4) Autonomic Ad-hoc Network Monitoring

Table 4: Autonomic Ad-hoc Network Monitoring: ETSI TS 103 194

Title	**Autonomic Ad-hoc Network Monitoring Scenario**
Description/Story Use Case	The scenario refers to autonomic network monitoring in a dynamic environment. Other services may also be deployed following similar principles, as discussed below (see also Figure 1 in ETSI TS 103 194 V1.1.1 on Network environment management driven by players). In the following scenario, the network administrator desires to have a complete view of the network topology and to be able to assess network conditions, e.g. calculate various performance metrics. An overlay network is automatically set up by participating nodes, which (overlay network) hide any details of the underlying infrastructure, such as links established or torn down, failure of nodes, mobility of nodes, etc. Any (monitoring) service may now be built on top of a small set of well-defined abstract APIs, which allow interactions between nodes and the rest of the overlay network. There is no need for centralised control or infrastructure in order to set up new services. All the necessary functionality is shared by peers in the network. Some functions are delegated to more than one node for higher reliability. Moreover, the overlay network is designed to be established autonomously with minimal end-host configuration and human intervention. Thus, it could be argued that rapid deployment of new functionality may be achieved in the network. The network monitoring scenario is realised in the following specific steps: 1) An autonomic node initially searches for neighbours in its proximity, and if successful, joins an ad-hoc network. 2) After being able to communicate with neighbours at the physical layer, it participates in a peer-to-peer overlay network by using pre-installed software. An overlay topology (e.g. ring) is formulated by all participating nodes in the ad-hoc network. While nodes join or leave the network, the overlay ring is autonomously updated by applying specific ring maintenance protocols. 3) Any nodes connected to the p2p network are able to store or retrieve information related to the services using a small set of functions that are based on Distributed Hash Tables (DHT). Autonomicity is derived by the fact that nodes do not need to address network topology changes, e.g. due to node failures. 4) When an autonomic node wants to provide a new service to its peers, it should retrieve the necessary data from the network. Data is stored beforehand by peering nodes in the overlay network using predefined keys, as discussed in the following examples. Therefore, each service is implemented through the cooperation of a large number of autonomic entities that interact by storing and retrieving meaningful keys across the overlay topology. In this way, the network administrator can achieve autonomic functionality that emerges in a decentralized manner without explicit action or control. EXAMPLE A: The provision of a visualisation service for an (ad-hoc) network requires knowledge of all the operational nodes/links/functions in the network. In an autonomic scenario, all the network nodes store topology data to one location which may be a network node. This storage location may be dynamically chosen. A common key, included in the pre-installed p2p software, is used for this operation. If necessary, data redundancy is achieved automatically by the selected peer to peer protocols without any intervention from the administrator or the network nodes. Consequently, all topology information is available to any node aiming to provide a new service. EXAMPLE B: The provision of a performance monitoring service for all the links in an (ad-hoc) network is based on similar techniques as in the previous example. The difference in this example compared to the previous one is that multiple keys are now necessary for storing monitoring information for each operational link in the overlay network. A simple function on the IP addresses of the nodes terminating a link may be used for generating necessary keys. This function is included in the pre-installed software of each node.
Network Environment(s)	Mobile Ad-hoc Networks –MANETs (dynamic topology, unreliable operation of nodes and links, and loose control of nodes) The scenario may also be applied in other environments such as fixed/wireless networks.

Title	**Autonomic Ad-hoc Network Monitoring Scenario**
Problems	In a dynamic environment with frequent topology changes and link failures, centralized approaches suffer from low service operational quality –e.g. performance is reduced when connectivity is not feasible to the central node-, have limited scalability (e.g. data is stored in a single node and service degradation is expected by increasing the incoming requests)), and resilience (e.g. the central node is a single point of failure). The creation of overlay networks is proposed as a decentralized solution for designing and providing (monitoring) services. These overlay networks are based on p2p protocols and provide storage and retrieval functionalities. Resources may be combined in a distributed manner and the following characteristics may be supported: scalability, decentralization, high availability of the provided services, fault-tolerance. However, p2p protocols are capable of handling dynamic incoming / outgoing nodes and registration / deregistration of resources but still under the assumption of a fixed topology and minimum uncertainty. Thus, specific mechanisms for topology formulation and maintenance have to be applied. These mechanisms have to be able to converge after network changes and not to impose high operational burden to the overlay network.
Functions Impacted by the need for automated management and AMC	The following autonomic management functionalities are provided: • *Self-configuration of the autonomic node*. Each autonomic node recognizes its neighbours, joins the overlay network and is able to store and retrieve data autonomously. • *Self-organization of the network* – establishment of the network and the communication links. Join and leave node requests are handled autonomously. • *Self-optimisation* – data and services are distributed uniformly among the participating nodes. The established overlay topology is maintained and updated after changes in the network.
Systems Involved	Network elements such as routers and devices for ad-hoc networking End Systems connected in a wireless infrastructure
Indicators / Evaluation criteria / Metrics to measure the value of automated management and autonomics	Network Bootstrapping: 1) How many messages are exchanged in order to achieve stabilization in conjunction with the network size and the network density? Storage and Querying: 1) What is the average cost (in messages) order to store specific amount of data in conjunction with the network size and the network density? 2) What is the average querying cost of a key? Reaction to topology changes: 1) How many messages are exchanged in order to achieve stabilization in conjunction with the network size and the network density? 2) How many messages are exchanged in order to achieve DHT stabilization in conjunction with the network size and the network density? One node chooses to query all Z keys. How many keys are unreachable? How is the redundancy ratio connected to the failure percentage?
Players	End users Network operator Manufacturer Service provider
Beneficiaries, and the Benefits brought by Automated Management and Autonomics	**System Administrators:** Responsible for network monitoring and management. Monitoring services are automatically adapted to network changes. **Vendors:** Implement necessary functionality to network elements such as routers routers. Network infrastructure has to support necessary functionality for supporting autonomic setup of monitoring services. **Application Developers:** Build new services without addressing any challenges regarding the underlying network infrastructure. **Manufacturers:** Design personal devices able to connect to any autonomic network with minimum software pre-installed. **End Users:** Accessing services provided by other peers with minimum user intervention and any support from (centralized) infrastructure.

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