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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

This White Paper is about Demo-1 and Demo-2 (of a series of Demos planned for 2018/2019) of the *ETSI PoC (Proof-Of-Concept) on 5G Network Slices Creation, Autonomic & Cognitive Management and E2E Orchestration; with Closed-Loop (Autonomic) Service Assurance for Network Slices; using the Smart Insurance IoT Use Case*

White Paper No.1
(of a series of White Papers expected from the ETSI PoC)

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ETSI TC INT AFI WG 5G POC

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Other White Papers:

- ***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 GANA Knowledge Plane for Autonomic Service Assurance of 5G Network Slices; and Orchestrated Service Monitoring in NFV/Clouds***

Executive Summary

ETSI (European Telecommunications Standards Institute) TC INT/AFI Working Group (WG) is running a PoC (Proof-Of-Concept) on ***5G Network Slices Creation, Autonomic & Cognitive Management & E2E Orchestration; with Closed-Loop (Autonomic) Service Assurance for the IoT 5G Slices (using Smart Insurance Use Case)***. The PoC is expected to run a series of Demos to demonstrate various aspects of relevance to 5G Network Slices Creation, Autonomic & Cognitive Management & E2E Orchestration; with Closed-Loop (Autonomic) Service Assurance for the IoT Slices (Smart Insurance) Use Case.
One of the key aspects being addressed by the PoC is the aspect of how to Build and Demonstrate the Telecom Operators' Desirable Framework for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices across Access, X-Haul (particularly Fronthaul and Backhaul) and Core Networks.
ETSI TC INT/ AFI WG has recently published the de-facto standard on the GANA (Generic Autonomic Networking Architecture) Reference Model—An Architectural Reference Model for Autonomic Networking, Cognitive Networking and Self-Management of Networks and Services [1][2]. ETSI TC INT/ AFI WG has since established that E2E Autonomic Service Assurance shall be achievable through the Federation of GANA Knowledge Planes (KPs) that implement components for autonomic management and control intelligence for specific network segments and domains. Autonomics in the realm of a KP needs to be complemented by lower level autonomics introduced in Network Functions (NFs), for the purpose of Holistic Multi-Domain State Correlation and resources programming by the GANA KPs for Access, X-Haul (particularly Fronthaul and Backhaul), and Core Networks.
The question of how to implement GANA-defined autonomic manager components (called autonomic functions) in physical network elements/functions (NEs/NFs) and Virtualized Network Functions (VNFs) and complementing them with autonomic manager components defined to operate in the realm outside of NEs/NFs (the realm of management and control systems for particular network architectures), i.e. in the realm called the GANA Knowledge Plane (KP), is being answered by ETSI TC INT/AFI WG Specifications such as ETSI TR 103 404, ETSI TR 103 495, and ETSI TR 103 473.

NOTE: The ETSI GANA Model and associated concepts are briefly described later in the in the paper, to help readers understand the PoC's Objectives.

This White Paper discusses some topics and associated challenges that have been addressed by Demo-1 and Demo-2 of the ETSI 5G PoC and continue to be discussed by the industry, namely:

- ***Smart Insurance Providers as Key Requesters and Consumers of 5G Network Slices delivered by Service Providers in fulfilment of Slice Requests***
- ***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 through the Federation of GANA Knowledge Planes***

Readers are encouraged to follow the developments, progression and the results of the ETSI 5G PoC (https://ntechwiki.etsi.org/index.php?title=Accepted_PoC_proposals)[3], as there are plans for a series of Demos planned to cover various aspects of the overall PoC in the timeframe 2018/2019 and beyond). For more background information on what has been addressed so far by the "**ETSI PoC on GANA in 5G Network Slicing**" and the future Demos in plan, readers can access Reports, Demo sheets and Slides at: https://ntechwiki.etsi.org/index.php?title=Accepted_PoC_proposals .

The PoC Consortium is not "closed-consortium", and welcomes new members in the course of the PoC duration, which goes beyond 2018/2019 timeframe. Contact details are given at the end of this White Paper, for those interested in the PoC results or joining the Consortium. This White Paper focuses on Demo-1 and Demo-2 of the 5G PoC and complements other White Papers that are based on Demo-2 and other Demos of a series of Planned Demos on various aspects of the overall ETSI 5G Network Slicing PoC, as more Demos are expected in the duration of the PoC over 2018/2019.

1. Problem Statement addressed by Demo-1 and Demo-2 of the ETSI 5G PoC

The newly desired Service Provider (SP)'s environment for digital services design, creation and delivery (service fulfilment) to service consumers (human, Verticals, objects) need to be smarter in the automation of processes, in supporting more autonomous on-demand service instantiation and consumption. There is also a need for supporting agility and flexibility in enabling to instantiate and deliver the services that the customer really wants anytime anywhere. In this respect, a customer as a Service Consumer is to be given a more active role by the Service Providers (SPs) in the dynamic service design and delivery processes and more generally in the whole Service life cycle (DevOps / CI / CD).
In this regard, SPs are departing from the traditional rigid model by which Service Providers used to handle all the processes solely without delegation of some of the processes to service consumers or third parties directly in such a way as to enable them to instantiate services on-demand wherever they need the services to be delivered by the SP's Networks and Service Delivery Platforms. Hence the Customer becomes a key actor within the Data-centric Digital Ecosystem.
These new SP's service delivery environments that are 5G Network Service -based and new Data-centric Digital Ecosystems are to interact and exchange personal information. At the end, they will only prevail if Service Provider first and then the other Partners/Actors of the Digital Service Ecosystem respect the customer's most important asset, which is their data. This is especially important in the "Insurance Business" that manages mainly personal information.
In this regard, Service Providers need innovative technologies to address increasing customer expectations and new regulation requirements such as the European GDPR and regulations in force in other regions. Customer service demands are becoming more and more challenging.

1.1. **Network Operators' Key Requirements that belong to the Problem Statement** and underpin the Demo-1, Demo-2

A Network Operator as well as a Service Provider shall support a Governance process to allow checking and verifying over time, Data traceability, provenance and placement when delivering E2E Services that span SP's domains (RAN, Fronthaul/Backhaul, Core Network) even partners' domains if partnerships is needed. For the Service Provider (SP), the success on operating and delivering various types of 5G Network Slices of varying requirements and SLAs (Service-Level Agreements) as services to various Service Consumers of the SP (including Smart Insurance Players as Network Slice Service Requesters and Consumers) is to be equipped with a ***Framework for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices***. Such a Framework must address the following key aspects:

- Federation of GANA Knowledge Planes (KPs) for E2E Autonomic (Closed-Loop) Service Assurance for 5G Slices. Such federated GANA KPs shall be achieved by the interworking of a GANA Knowledge Plane for RAN (realized through Centralized SON (Self-Organizing Networks) with cognitive SON functions), GANA Knowledge Plane for the Transport Network (e.g. x-haul/Backhaul) and a GANA Knowledge Plane for the Core Network, for correlated assurance of RAN Slices, Backhaul Slices and Core Network Slices. The concept of the GANA Knowledge Plane is described below and in the corresponding ETSI documents on the GANA (Generic Autonomic Networking) Reference Model for Autonomic Networking, Cognitive Networking and Self-Management of Network and Services (refer to ETSI White Paper No.16] and the recently published ETSI TS 103195-2 GANA Technical Specification).
- From deployment point of view, various flavors / options may be envisioned w.r.t GANA KPs. For instance, having a Knowledge Plane designed and implemented for each specific network segment (or domain) rather than having a single large Knowledge Plane that covers multiple segments (a scenario that may be motivated by various incentives (based on technical or administrative or even business models considerations)).
- Autonomics is the enabler for the realization (implementation) of "***Self-Driving Networks***" that are "***Self-Aware***".

- How NE (Network-Element) internal Autonomics Control-Loops and Distributed Control-Loops across NEs in the RAN, Fronthaul, Backhaul and Core Network complement higher Level Autonomics Control-Loops in achieving E2E Autonomic Service Assurance for 5G Slices. Noting that for the RAN, low level autonomics is realized through D-SON (Distributed SON), which is then complemented by higher level autonomics (namely C-SON), and that autonomics for the other network segments beyond RAN is also required.

- KPIs specific to 5G network segment slices and their communication to the Autonomics Decision-making Elements/Engines and associated Control-Loops for Slice SLA Assurance; and KPIs exchanged between the GANA Knowledge Planes (KPs) to effect E2E Collaborative Autonomic Service Assurance (Self-Optimization) for 5G Slices by the Knowledge Planes
- In 5G, it is envisaged that SPs will offer to various types of network service consumers the flexibility to instantiate and consume network services on-demand and with agility. Among such network services would be "Network Slice –as-a-Service", and Verticals providing IoT Services Delivery are some of the SP's customers that will trigger the creation of Network Slices in the SP's End-to-End environment—spanning Access Networks, x-Haul (Fronthaul and Backhaul) and Core Networks. Insurance Platforms *are bound to be some of the SP external systems that will trigger the creation of Network Slices in an SP environment on-demand, as they would be an actor in slice service instantiation processes.*
- The Service Assurance for Network Slices should be achieved through E2E Closed-Loop (Autonomic) Service Assurance of the E2E network slices by means of a Federation of Autonomic Service Assurance Components that collectively work together in an E2E fashion to deliver Network Slices assurance and adaptive network resource programming across the network segments delivering the aggregate network slices, e.g. across Access Networks, x-Haul (Fronthaul and Backhaul) and Core Networks. SON (Self-Organizing Network) functions for the 5G RANs should interwork with GANA components such as GANA Knowledge Plane components to deliver E2E Autonomic (Closed-Loop) Service Assurance of Network Slices for Self-* features for network slices, such as **Self-Optimization and Self-Healing of Network Slices.**
- GANA empowered Autonomic (Closed-Loops) Service Assurance for 5G Network Slices, as a means to achieve E2E Autonomic (Closed-Loop) Slice Assurance through Federation/Interworking of GANA Knowledge Planes for RAN (i.e. C-SON as KP for RAN), Fronthaul & Backhaul, Edge, and Core Network (e.g. EPC or the Service-Based Architecture (SBA)); complemented by low levels autonomics introduced in the Network Elements/Functions (NEs/NFs) of the RAN, Transport and 5G Core Network; for Multi-domain state correlation and dynamic and cooperative self-adaptive network services programming in and across the various domains (RAN, Fronthaul, Edge, DC, Backhaul, Core Network)
- Integration/Convergence of Autonomic (Closed-Loop) Service Assurance with Orchestrated Assurance
- Considering IPv6 in the picture on 5G, it is worthy to note that while IPv6 is expected to play a big role in 5G (e.g. in mMTC 5G slices) there are IPv6 specific features that bring value to 5G Slicing, e.g. the use of Extension Headers in grooming telemetry information required for driving adaptive (autonomic) service assurance of slice specific traffic flows

1.2. How the White Paper is organized

In order to understand the concepts and network operators' requirements addressed by Demo-1 and Demo-2 of a series of Demos planned for the 5G PoC, this white paper first gives a brief introduction to the ETSI GANA Model and the recently published ETSI Standard (ETSI TS 103 195-2)[2], and then moves on to describe the GANA principles for autonomic management and control for networks and services (including the concept of autonomic service assurance).

The paper also presents the value of Multi-Layer Autonomics and the integration of the GANA Knowledge Plane with Orchestrators, SDN Controllers, and OSS/BSS systems. The paper then summaries the Objectives addressed by Demo-1 and Demo-2

The paper also presents the **Capabilities of QualyCloud a**nd **Cellwize Solutions** w.r.t **Smart Insurance Platforms—platforms that require "*5G Network Slice as a Service*" to enable to operate connected car IoT services** and **C-SON Evolution for 5G and C-SON as GANA Knowledge Plane for the RAN,** respectively.

The QualyCloud Capabilities address the *Requirements of Key Requesters and Consumers of 5G Network Slices* that should be delivered by Service Providers in fulfilment of *Slice Requests* received from the external slice requesters via self-care portals. while the Cellwize 5G SON capabilities address the outlined Telecom Operators' Requirements tailored to *Telecom Operators' desired Framework for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices*.

The White Paper then looks into Vendors' (suppliers) Business View of the Overall 5G PoC, more background details on the ETSI 5G PoC, ETSI-GANA Model as key Enabler for 5G, and the value of Federation of GANA Knowledge Planes for E2E Autonomic (Closed-Loop) Service Assurance across the various network segments/domains.

2. Brief introduction to the ETSI GANA Model for Autonomic Networking, Cognitive Networking and Self-Management

ETSI TS 103 195-2 [2] defines the concept of 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).
The ETSI GANA Standardized Framework for Autonomic Management and Control (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 that provides for the space to implement complex network analytics functions performed by interworking Modularized Autonomic Managers (called Decision Elements (DEs)). The KPs DEs run as software in the Knowledge Plane and drive *self-* operations such as self-adaptation, self-optimization* objectives for the network and services by programmatically (re)-configuring Managed Entities (MEs) in the network infrastructure through various means possible: e.g. through the NorthBound Interfaces available at the OSS, Service Orchestrator, Domain Orchestrator, SDN controller, EMS/NMS, NFV Orchestrator, etc.

The GANA Knowledge Plane is a modularized Intelligent Management and Control Functional Block, and consists of multiple Autonomic Managers called Decision Elements (DEs). In contrast to non-modularized management systems, each Autonomic Manager is expected to be a module (as atomic block) and that it should address a very specific "management domain (i.e. scope of management aspects/problems)" such that it can run as a "micro service".
Examples of Autonomic Managers are: *Autonomic Fault Manager; Autonomic Configuration Manager; Autonomic Mobility Manager; Autonomic Security Manager; Autonomic QoS_&_QoE Manager; Autonomic Routing Manager; Autonomic Monitoring Manager; etc*.
Autonomic Manager components of the GANA Knowledge Plane are "macro" autonomic managers that drive logically centralized and network-wide but slow control loops that operate in "slower timescale" than similar control-loops introduced to run in Network Elements (NEs) and operating as "faster timescale control-loops (i.e. the so-called fast control-loops)".
Macro autonomic managers are to be complemented by "micro" Autonomic Manager components 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 policy-control "micro" autonomic managers (so-called GANA Level-2 and Level-3 in the ETSI TS 103 195-2).

ETSI TC INT AFI WG's work on autonomic networking involves introducing network nodes/functions self-manageability (autonomics) properties (*e.g. self-configuration, self-diagnosis, self-repair, self-healing, self-protection, self-awareness, etc*.) within network nodes/functions themselves and enabling distributed "*in-network*" self-management within the data plane network architectures (and their embedment of "thin control planes"), as well as introducing autonomics in the associated management and control architectures.

The three key Functional Blocks of the GANA Knowledge Plane are summarized below:

- **GANA Network-Level DEs**: **GANA** *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 be 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 ETSI TC INT/ AFI WG's "GANA" (Generic Autonomic Networking Architecture) reference model combines perspectives on "Micro-Level" autonomics (defined by the so-called GANA levels-1 to Level-3 illustrated in Figure 1) and the interworking with "Macro-Level" autonomics (realized by the GANA Knowledge Plane—the so-called GANA level 4). The GANA model defines 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, including the role of Artificial Intelligence (AI) algorithms such as Machine Learning(ML) and Deep Learning(DL) in all this. This ETSI GANA Framework is illustrated in Figure 1.

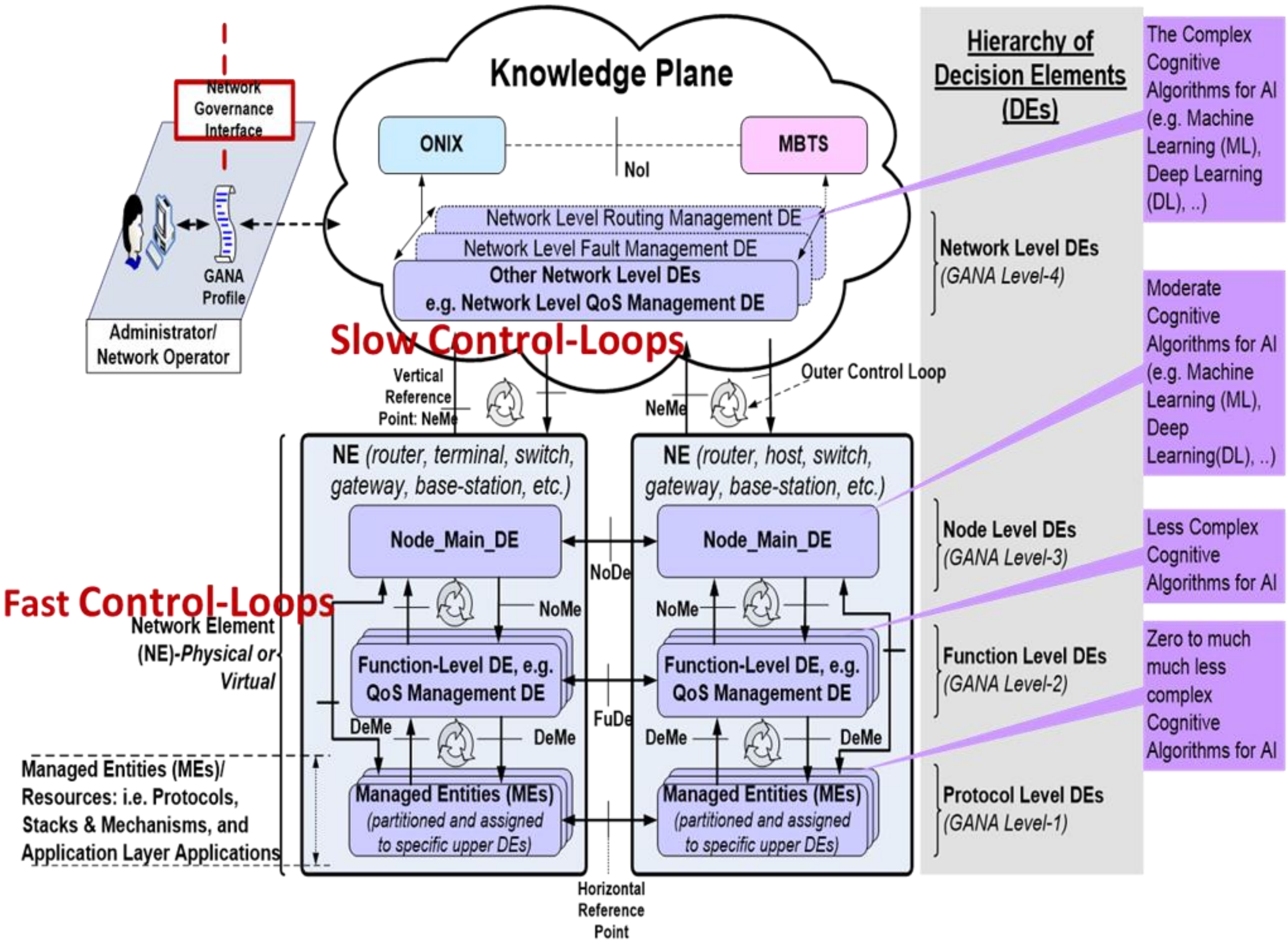


Figure 1: *Snapshot of the GANA Reference Model and Autonomics Cognitive Algorithms for Artificial Intelligence (AI)*

3. DEs as the autonomic management and control services that dynamically(adaptively) program (configure) specific Management Entities (MEs) embedded within Network Elements (NEs) or Network Functions (NFs) or Services associated with an NF

DE algorithms, which determine the DE's intelligence on when a DE adaptively decides to (re)-configure its assigned (by design) Managed Entities (MEs), are expected to vary according to the DE vendor/supplier. As such, algorithms (just like in the case of SON (Self-Organizing Networks) Algorithms) cannot be standardized as they are the means to provide for DE vendor innovation and differentiation as described in ETSI White Paper No.16 and ETSI TS 103 195-2[2]. Decision Elements (DEs) are characterized as follows: Centralized Control Software Logics (those meant to operate in the GANA Knowledge Plane), and Distributed Control Software Logics (those meant to operate in NEs/NFs). The two types of DEs operate in different time-scales (as described in ETSI TS 103 195-2) but interworking harmoniously in realizing autonomic behaviors (*self-configuration, self-optimization, and other self-* operations DEs perform on their Managed Entities (MEs)*) [2]. DEs may be "loaded or replaced" in Network Elements (NEs) or NFs in general and in the GANA Knowledge Plane, bringing about the notion of "Software-Driven or Software-Empowered Networks", as DEs that exhibit better Algorithms and Intelligence may continuously be innovated by DE vendors/suppliers.
The following points characterize the value of DEs introduced into any network architecture and its associated management and control architecture:

1. **The DE concept should be specialized for a specific type of autonomic management and control domain, e.g.:** *QoS-management, Security-management, Mobility-management, Fault-management, Resilience & Survivability, Service & Application management, Forwarding-management, Routing-management, Monitoring-management, Generalized Control Plane management*. ETSI TS 103 195-2 defines a set of such domains and associated DEs (which can be viewed as specialized services at run-time) that can be instantiated into Network Functions (NFs) of a network architecture (such as a backhaul or core network architecture) and also in the associated management and control realm of the network architecture. Such DEs should be injected into a Network Function or injected within a service associated with a Network Function (NF). Any DE in the autonomic network node (network element/function) of the network infrastructure should have a mirror Network Level DE in the GANA Knowledge Plane for the particular network segment which operates on network wide views and shall policy-control the corresponding DE in the node (NE/NF). Managed Entities (MEs) should be autonomically orchestrated and/or configured by their responsible DE as part of the overall functionality for the operation of the Node (Network Element/Function). The human (Network Provider) needs to have the ability to govern any DEs i.e. configure and control the behavior of a DE and its mode of operation ("open-loop" or "closed-loop"). Any DE should be governable to be configured to operate in Open-Loop or Closed-Loop Mode, and to consume policies and other inputs provided to it by Network Operator's automated management tools used by the human operator.
2. The Interaction and coordination between DEs should take into consideration the Hierarchical nature of control loops and peer to peer DE reference point defined in the ETSI TS 103 195-2.
3. Like any functional entity, a DE should be managed, and operations and primitives needed to manage a DE as defined in ETSI TS 103 195-2 should be implemented by a DE. The operational goals of a DE should be clearly defined, even without explicitly exposing the algorithm of the DE.
4. DEs should be designed and linked (associated with) a specific Network Domain/Segment, Network Architecture Layers and their outer Management & Control Architecture Layers associated with a specific Network Domain/Segment. Network domains can be Access Network, Edge, X-Haul (particularly Fronthaul and Backhaul) Network, Core Network, Transport Network, Data Center Network or other types of network domain. Network Architecture Layers include the GANA Levels (node-level, function-level, protocol level) defined by the GANA Model. Management & Control Architecture Layers include the GANA Knowledge Plane (GANA network-level) layer and the

Business and Service Management Layers that provide inputs that drive and govern the Knowledge Plane's autonomic operations.

5. E2E Autonomic Service Assurance of E2E Network Services (including 5G Network Slices) shall be achievable through the ***Federation of GANA Knowledge Planes (KPs) for specific network segments and domains***, and ***complemented by lower level autonomics in Network Functions (NFs),*** for a "*Holistic Multi-Domain State Correlation and adaptive resources (re)-programming*" by the **GANA KPs** for ***Access***, ***Backhaul***, and ***Core Networks (as illustrated later).*** *The scope of Federation of Knowledge Planes may be extended to cover other domains beyond the Core Network, such as a Data Center Network hosting some Telco-Cloud Network Functions or even IT Applications.* Service Providers seek to deploy ***Framework for E2E Autonomic (Closed-Loop) Service Assurance for Network Services*** as illustrated later. ETSI TS 103 195-2 provides guiding principles that help implementers to implement Federation of GANA Knowledge Planes across multiple domains (including administrative domains). Within the same Knowledge Plane of a particular network segment (e.g. Access or Core Network) DEs exchange knowledge and synchronization or coordination messages directly among each other. Knowledge acquired in different network domains or layers such as the GANA Knowledge Plane Layer may be exchanged between the domains and layers through the ONIX system as illustrated later along with illustration of federation of Knowledge Planes for various domains.
6. A DE service (the DE itself), particularly for the case of the GANA Knowledge Plane DEs, can be replaced/upgraded/controlled by the Network Operator at any time during the operations lifecycle of the network. DEs MAY be "loaded or replaced" in NFs and in the GANA Knowledge Plane, bringing about the notion of "*Software-Driven or Software-Empowered Networks*", as DEs that exhibit better Algorithms and Intelligence may continuously be innovated by DE vendors/suppliers.
7. Network operator may develop or select on a marketplace some of the DEs according to the business needs of the network operator. Network operator should be able to test, certify, trust, validate any DEs.
8. ETSI TS 103 195-2 provides guidance on how legacy management systems could be used in parallel with Self-management DEs implemented by the GANA Knowledge Plane during the transition phase, in order to smoothly upgrade legacy management by interworking them with the "self-management enabling" Knowledge Plane.

4. Collaboration/Coordination of Autonomic Functions (DEs) through synchronization of actions/policies on the programming of their corresponding Managed Entities (MEs)

There are policies or actions of Autonomic Functions (DEs) that require Collaboration/Coordination of Autonomic Functions (DEs) through synchronization of actions on the programming of their corresponding Managed Entities (MEs). Some coordination/synchronization may involve only "a set" of DEs (not all) in the Knowledge Plane and some may require the coordination/synchronization of "all" the DEs. Figure 2 below illustrates this aspect of the need for Collaboration/Coordination of Autonomic Functions (DEs). This subject is linked to the topic of addressing stability of control-loops and optimal behavior and state of operation of the autonomic network and its associated autonomic management and control operations. ETSI TS 103 195-2 covers this subject of coordination of autonomic functions and achieving stability of control-loops in GANA in much more detail.

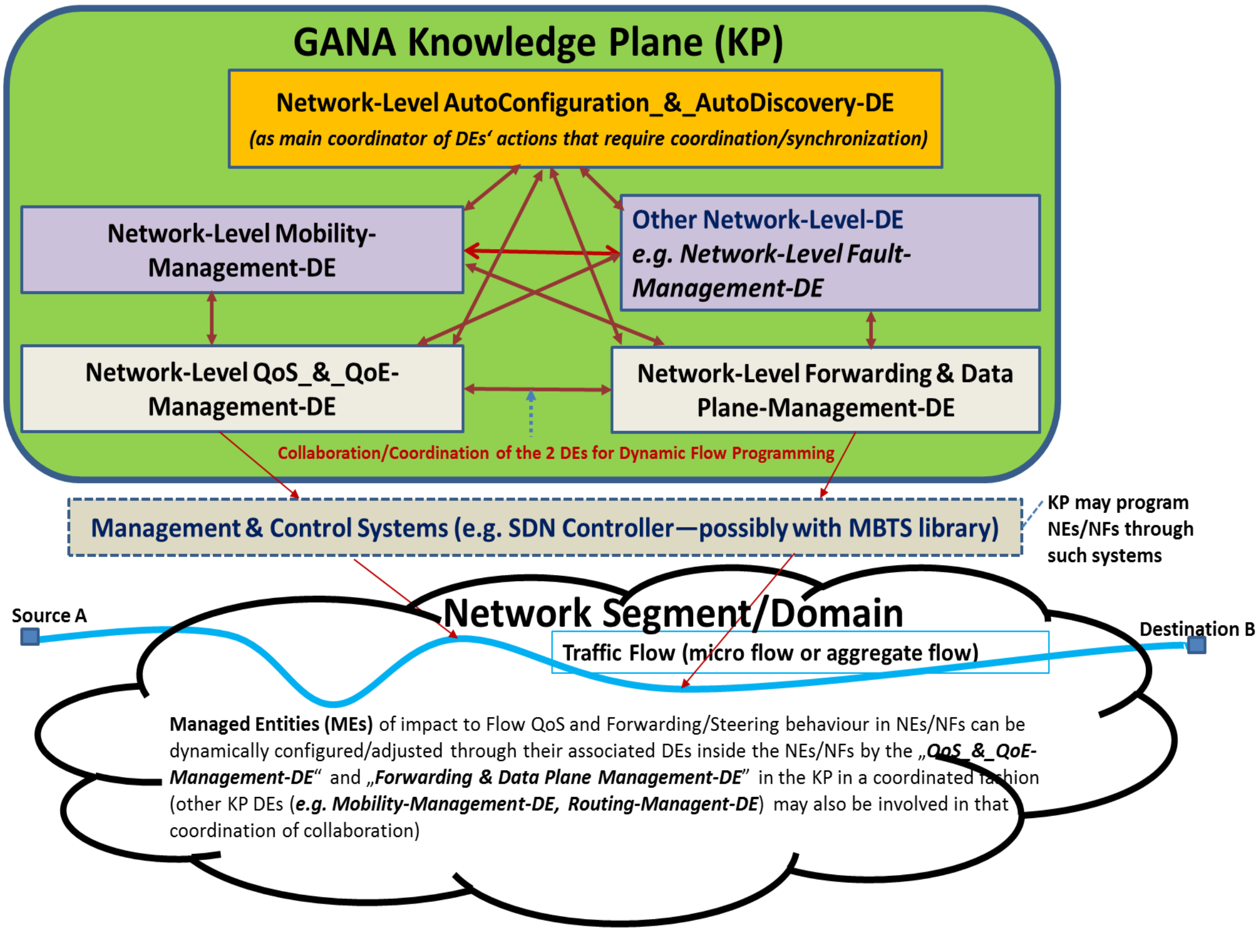


Figure 2: Need for collaboration or coordination of Autonomic Functions (DEs) on certain actions or aspects that are better addressed through collaboration/coordination

5. Multi-Layer Autonomics and the integration of the GANA Knowledge Plane with Orchestrators, SDN Controllers, and OSS/BSS systems

Figure 3 illustrates the integration of GANA Knowledge Plane with other management and control types of components/systems, as well as multi-layer autonomics (more details on this subject can be found in ETSI White Paper No.16 and ETSI TR 103 473), i.e. the abstraction levels at which Autonomic Functions (Decision Elements) can be implemented (as illustrated on Figure-1, regarding the ETSI GANA Model).

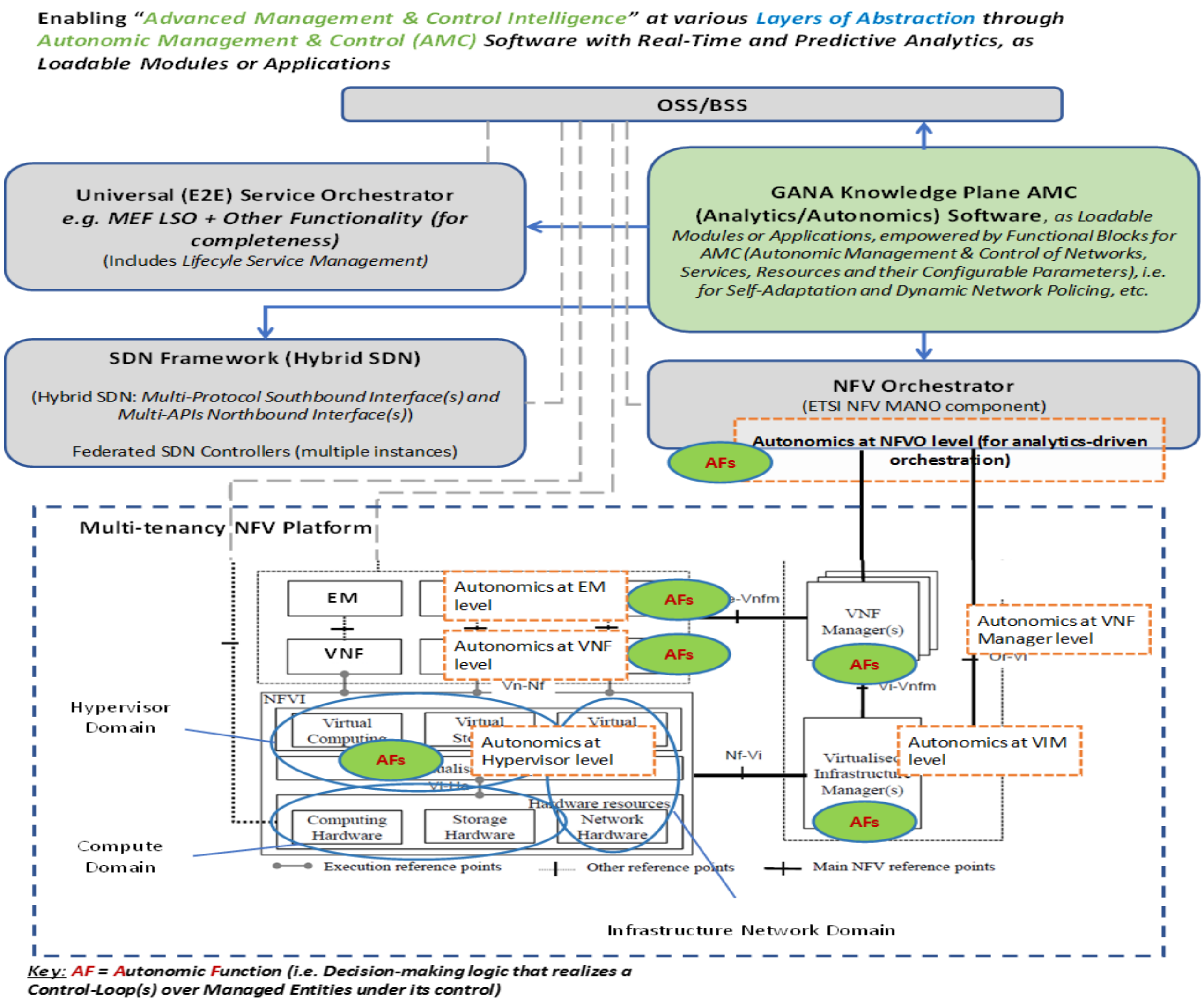


Figure 3: Multi-Layer Autonomics and the integration of the GANA Knowledge Plane (KP) with Orchestrators, SDN Controllers, and OSS/BSS systems

GANA Knowledge Plane that is an integral part of Management and Control Systems that provides for the space to implement complex network analytics functions performed by interworking Modularized Autonomic Managers (called Decision Elements (DEs) in GANA terminology) that run as software in the GANA Knowledge Plane and drive self-* operations such as self-adaptation, self-optimization objectives for the network and services by adaptively programmatically (re)-configuring Managed Entities (MEs) in the network infrastructure through various means possible: e.g. through the NorthBound Interfaces available at the OSS, Service Orchestrator, Domain Orchestrator, SDN controller, EMS/NMS, NFV Orchestrator, etc.
Various management and control systems, such as OSS/BSS-OSS, E2E Service Orchestrator, and SDN controller, NFV Orchestrator, should all be viewed collectively as data sources or events sources by the GANA Knowledge Plane. This is because the GANA KP is supposed to be the center of consolidated knowledge about the network and intelligence for autonomic and cognitive management and control of the network infrastructure based on data and knowledge and events obtained from the various systems by the GANA Knowledge Plane. Also because Complex Event Processing (CEP) over events from the various systems is to be performed by the GANA Knowledge Plane as discussed in ETSI White Paper No.16 [1] and GANA Technical Specification [2]. And in turn, the GANA Knowledge Plane DEs may dynamically and selectively fire commands (thanks to the cognitive and analytics algorithms employed by the KP DEs) into any or some of the systems.

This depends on the target systems the GANA KP DEs determine should be used by the DEs' attempt to adaptively and intelligently instantiate, scale-in, scale-out or program the PNFs and VNFs of the underlying network infrastructure.

For example, the GANA Knowledge Plane can fire commands into the E2E Service Orchestrator in attempts to achieve analytics-driven orchestration, as may be determined by the Decision Elements (DEs) of the Knowledge Plane.
Another possibility is that the KP could fire commands through the OSS, or through the SDN Controller, etc., instead, or in combination to firing commands into the E2E Service Orchestrator. As such, the GANA Knowledge Plane is to be viewed as the "brain" for which implementers should design and implement advanced Autonomic/Cognitive Management & Control (AMC) DE Algorithms that can program network infrastructure via any of the systems available for that and according to the capabilities available of the systems' interfaces.
The GANA Knowledge Plane can be viewed as an Advanced Analytics Platform that also retrieves Health Scores Data, Monitoring/Telemetry Data, Topology and Configuration Data from the SDN Controllers for the Production Network and from NEs, and use the data in making the complex decisions in the Closed-Loop (Autonomic) Management and Control operations on the network infrastructure.

NOTE: As illustrated later on Figure 7, a GANA Knowledge Plane can be designed and implemented for a specific network segment(domain), rather than having a single large GANA Knowledge Plane that covers multiple segments—as this may follow various incentives (based on technical or administrative or even business models reasons). And so in interactions with other management and control systems such as OSS, Orchestrators and SDN controllers, a GANA Knowledge Plane for a specific segment programs state into the underlying network infrastructure under its responsibility, and participates in federated operations (dynamic end-to-end network state programming) in collaboration with Knowledge Planes for other network segments/domains.

6. Technical view of the Overall 5G PoC

The plan of the ETSI 5G PoC is to use this 5G Network Slicing PoC as an instrument for the following aims:

(1) Enabling the "Telecom Operators" to provide a clear holistic picture to "Solution Suppliers" as to how their 5G networks would look like and the complementary roles to be played by the following technologies/paradigms in 5G: ETSI GANA components for Closed-Loop (Autonomic) Management & Control of network resources and parameters in Autonomic (Closed-Loop) Service Assurance of Network Slices; SDN; NFV; E2E Orchestrators; Big-Data Analytics for Autonomic/Cognitive Management & Control; SON (Self-Organizing Networks); specialized interfaces (including the network governance interfaces); Network Automation; and GANA intelligence software for Autonomic/ Cognitive management and control of networks and services (i.e. Software for Autonomic (Closed-Loop) Service Assurance); and the Telecom Operator's Desired Framework for Dynamic Probing for Orchestrated Assurance and the Integration/Convergence of Autonomic Service Assurance with the Orchestrated Assurance of Newly Instantiated Network Services such as 5G Network Slices and Service Chains:

(2) Breaking from silos on standards and R&D efforts linked to the complementary emerging networking paradigms, by promoting and progressing the Unifying and Harmonizing Architecture that integrates the ETSI GANA, SDN, NFV, E2E Orchestration, and specialized Big Data Analytics for Autonomic / Cognitive Management & Control;

(3) Enabling "Solution Suppliers" of the following solutions/components and other players to use the PoC instrument to identify gaps in standards and initiate activities (e.g. in ETSI TC INT AFI Working Group) to close any gaps in Autonomic Management & Control (AMC) standards that may be identified during the PoC. "Solution Suppliers" of the following solutions/components are being engaged in the 5G PoC and the various Demos being planned for the 2018/2019 timeframe and beyond:

  a. SON (both C-SON and D-SON)—i.e. Centralized SON and Distributed SON (Self-Organization Network);
  b. SDN (Software Defined Networking);
  c. NFV (Network Functions Virtualization);

d. GANA Knowledge Plane (with the Autonomics/Analytics Algorithms, Knowledge Synthesis and Representation from raw monitoring data, and the dynamic application of various forms of Knowledge obtained from diverse data/information sources by the GANA Knowledge Plane's Decision-making-Elements (DEs) in realizing the *Self-Adaptation (e.g. Self-Optimization) management and control operations for Network Resources and Parameters for the overall Closed-Loop Assurance of Network Slices)*;
e. Probing and Service Assurance Platforms that should act as data/information sources to the GANA Knowledge Plane's DEs,
f. Data Analytics required to be performed or exploited by GANA DEs instantiated (injected) in the network infrastructure Network Elements (physical or virtual) and in the GANA Knowledge Plane;
g. Network Infrastructure Network Elements (Physical and Virtual Network Functions);
h. RAN elements Cloudification Vendors.
i. Traffic Monitoring Solutions Suppliers for Programmable Traffic Monitoring Fabrics that enable On-Demand Monitoring and Feeding of Knowledge into the GANA Knowledge Planes for E2E Autonomic Service Assurance of Network Services (including 5G Network Slices), and Components/Solutions for Orchestrated Service Monitoring in NFV/Clouds

Figure 4 below depicts high level design principle of the PoC ecosystem and associated actors/roles relationships and interactions. Two main actors are considered at 5G operation time (run-time):

- a) **Network Slice Provider (SP)** with its associated partners (5G RAN Vendors, 5G X-Haul Network Vendors, 5G Core Network Vendors, 5G OSS & Network Slice Management Software Vendors, Programmable Traffic Monitoring Fabrics Vendors, Probing Vendors, GANA Algorithms and Software Components Developers and Suppliers, 5G BSS Vendors, 5G SON Vendors, …) whose components are required by an SP in creating, delivering, operating and assuring the four Network Slice Types: eMBB (SST 1), uRLLC (SST 2), IoT (SST 3), V2X (SST 4)

- b) **Network Slice Customer** or Network Slice Consumer who orders/ Self-Orders via a dynamic Ordering API the required Network Slice Types according to dynamic SLAs per Network Slice Type by interacting with the Network Slice Provider's BBS (Network Slice Self-Care Portal)

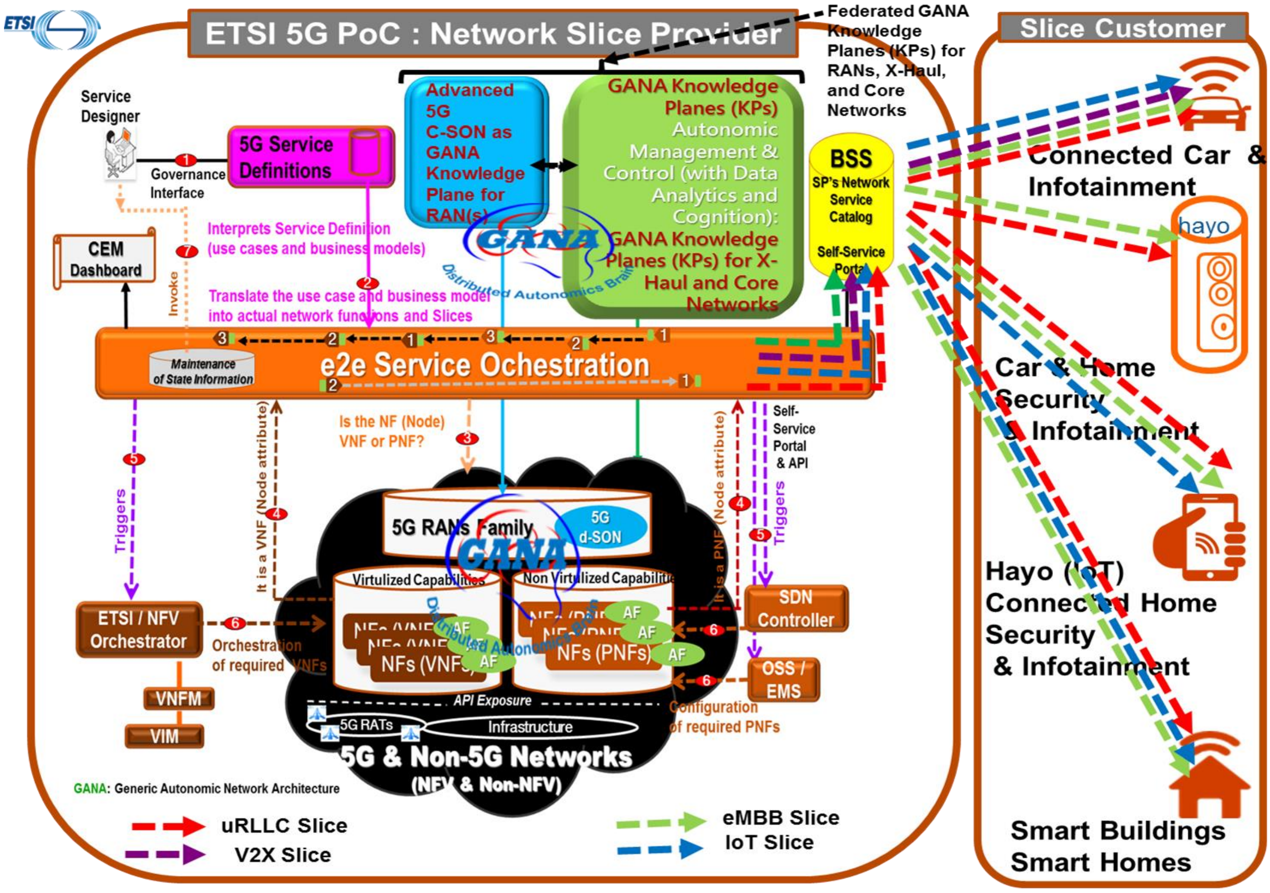


Figure 4: The depiction of the high level design principle of the 5G PoC ecosystem and associated actors / roles relationships and interactions

6.1. Description of the Network Slice Life Cycle Management (choreography)

1) Slice Designer (Human Operator), via the Governance API, accesses its 5G Slice Design / Service Definition Tool-Chain (pink box) and stores the Network Slice Template once populated, in a repository. **NOTE:** This process is automated in the case of a self-care portal through the BSS that can be used by external customers
2) Network Slice Template is pushed to the E2E Service Orchestrator
3) E2E Service Orchestrator interacts with ETSI MANO components, SDN Controllers and Legacy OSS to translate the content of the Template onto required VNFs / PNFs (RAN ones (including MEC (Mobile Edge Computing) ones) and Core Network ones) which are stored in the Virtualized Capabilities (Network Functions) Repository and in the Non-Virtualized Network Functions Repository (for Core Network). The diagram shows a dedicated Repository for RAN capabilities. All those capabilities are executed on the substrate layer (Hybrid Infrastructure: Black Cloud)
4) The descriptions (descriptors) of the identified (the required) VNFs and PNFs are sent to E2E Service Orchestrator
5) E2E Service Orchestrator launches Network Slice Life Cycle Management process
6) The Network Slices ordered by the customers via Service Provider's BSS (Yellow Box) are instantiated, configured and delivered to each of the four Customers (represented by the 5G applications) at the right hand side of the diagram.

7) GANA Knowledge Plane and "Distributed GANA" (Green boxes) DEs embedded in the VNFs and PNFs as AI / ML/ Cognitive algorithms along with Hybrid SON (Centralized and distributed: Blue Boxes) take care of configuration of the NEs (Network Elements, i.e. PNFs and VNFs) in the infrastructure if not already performed through the traditional management systems, and then proceed to perform E2E federated Autonomic (Closed-Loop) and Cognitive "Service Assurance" of each Network Slice Instance a Customer is consuming.
8) BSS (Yellow Box) embeds the Network Slice Billing System that shall offer billing capabilities per Network Slice Instance, enabling the billing of each Network Slice Instance individually, in the same way as a 5G OSS that shall offer management capabilities per Network Slice instance as an "Individual (sole) Network Slice Instance Manager".

7. The Four 5G Applications considered in the Overall 5G PoC's Network Slicing Use Cases

Four 5G Applications are considered in the Overall PoC's Network Slicing Use Cases. Whereby, each application (e.g. Smart Insurance Application) is ordering the required Network Slices via an order API interacting with Network Slice Provider's BSS. The table below depicts the mapping between PoC targeted Applications to required Network Slice Types.

Application	Network Slice Type required
Connected Car & Infotainment	• eMBB (SST 1) • uRLLC (SST 2) • mIoT (SST 3) •
Car & Home Security & Infotainment	• eMBB (SST 1) • uRLLC (SST 2)
Hayo (IoT) Connected Home Security & Infotainment	• eMBB (SST 1) • muRLLC (SST 2) •
Smart Buildings & Smart Homes	• eMBB (SST 1) • uRLLC (SST 2) • mIoT (SST 3)

8. 5G Slice Provider and Consumer Business View of the Overall PoC (consisting of multiple Demo Cases executed and in plan for 2018/2019 timeframe)

The overall PoC is looking into the practicalities of delivering Smart Insurance in complex digital environments while protecting user privacy, while taking into consideration Smart Insurance Providers as Key Requesters and Consumers of 5G Network Slices Delivery Services by Service Providers. Smart Insurance creates a fully customer-oriented ecosystem, centered on a platform that connects every stakeholder in the insurance business – insurance companies, brokers and their customers — in order to digitize, secure and automate all transactions.

The ecosystem covers the complete 'Business to Business' (B2B) and 'Business to Business to Consumer' (B2B2C) process management, from the stakeholder to the customer, including customer onboarding, contract management, claims handling and extending as far as confidential medical records management.

The 'Smart Insurance' lifecycle is further enhanced by connected devices, including the connected car, which allows offering flexible coverage perfectly adapted to every customer.

Creation of an end-to-end workflow from the user to all parties
Smart Insurance enables creation of an ecosystem specially built for the insurance stakeholders allowing the end customer to contract insurance services online and follow the complete lifecycle of their insurance policy through a secure platform, while allowing interaction with all Parties of the Ecosystem. The workflow includes the points when a Smart Insurance Provider issues requests for 5G Network Slices Delivery Services by a Service Provider. Figure 5 below illustrates a Smart Insurance ecosystem.

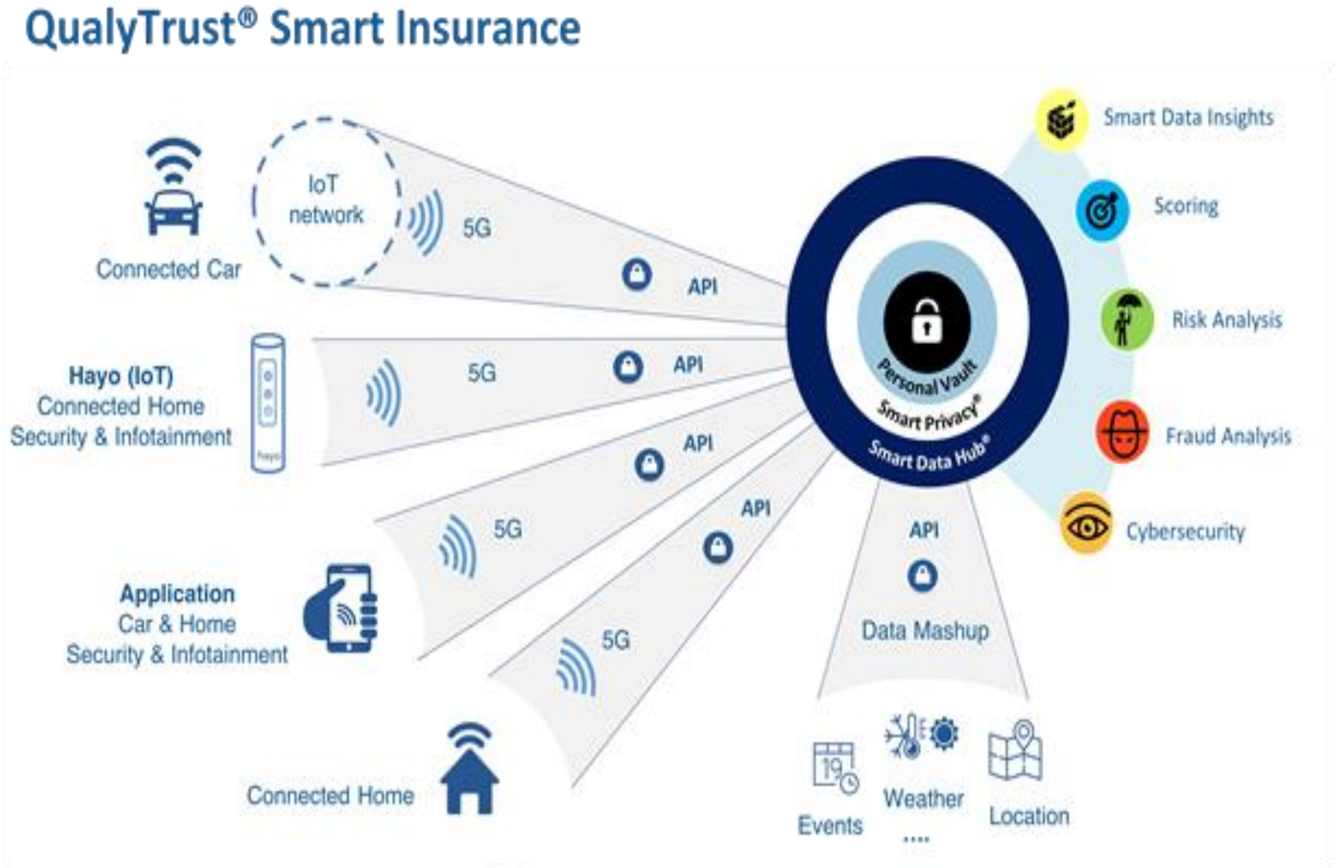


Figure 5: The Smart Insurance Ecosystem

Enforcing end-user Privacy in Usage-Based Insurance (UBI) and or IoT-Based Insurance
Usage-based insurances are migrating from "declarative" to "IoT-enabled" usage of a service/good. In the context of connected cars, ***Pay As You Drive (PAYD)*** refers to an insurance calculated dynamically according to the kilometers driven. In the near future, environmental sensors in houses and even in cities will have an impact on tariffs.

Probably, the most sensitive usage of IoT in Insurance concerns health Insurance or mortgage Insurance: even though existing processes are simple, mandating a clear separation between commercial processes and health-related communication is essential. Such separation must be driven by clearly defined rules, embedded within the Smart Insurance platform.

With a "privacy-enabled" workflow, and providing sealing between parties and their roles, end-to-end privacy can be enforced.

Smart Insurance, privacy and the new General Data Protection Regulation
After four years of work, the European parliament has voted the new General Data Protection Regulation (GDPR), re-enforcing the principles of Privacy by Design, consent, the right to be forgotten and data portability. All stakeholders are obliged to enforce GDPR in 2018. In that context, the 5G ecosystem we create to support the PoC use cases must ensure the law (GDPR) will be applicable in the PoC timeframe.

9. Vendors' Business View of the Overall 5G PoC: Supplying GANA conformant Software for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices and required Programmable Traffic Monitoring Fabrics and Solutions for Orchestrated Assurance

The ETSI White Paper No.16 describes the two categories that determine the actors or players the GANA model is addressing, namely: Suppliers (vendors) of GANA Functional Blocks (FBs); and Provider of assets required by the developers of GANA Functional Blocks (FBs).
ETSI TC INT AFI WG is a provider of assets (such as Specifications and Technical Reports (TRs) on Use Cases Scenarios and Requirements for introducing Autonomics in Network Infrastructure Elements/Functions of specific standardized reference network architectures (e.g. BBF (Broadband Forum architectures, 3GPP architectures, etc.) and their associated management & control architectures and systems) required by the developers of Autonomics Functional Blocks. Those provided assets are in form of TR documents on how to introduce autonomics in network architectures such as Broadband Forum (BBF) (see ETSI TR 103 473) and 3GPP Backhaul and Core Network Architectures (see ETSI TR 103 404).

The business value described in ETSI White Paper No.16 for Suppliers (solution vendors) of GANA Functional Blocks (FBs) concerns the following players: ISVs (Independent Software Vendors); Network Traffic Monitoring Solution Vendors, and Networking Equipment Manufacturers. All of such players can be suppliers of GANA AMC software such as Decision Elements (DEs) and their associated vendor differentiated autonomics Algorithms (e.g. Artificial intelligence for dynamic configuration and control of resources and parameters); GANA MBTS; GANA ONIX; and GANA Knowledge Plane Software in general.

Remark: Demo-2 was mainly focused on Suppliers of GANA conformant Autonomic (Closed-Loop) Service Assurance pertaining to the GANA Knowledge Plane for the Transport Networks and Core Networks, as well as Suppliers of Programmable Traffic Monitoring Fabrics that enable On-Demand Monitoring and Feeding of Knowledge into the GANA Knowledge Plane for Autonomic Service Assurance of Network Services (e.g. 5G Network Slices); and Suppliers of Solutions for Dynamic Probing for Orchestrated Assurance within NFV/Clouds (Virtualized Environments) and the Integration/Convergence of Autonomic Service Assurance with Orchestrated Assurance for Newly Instantiated Network Services (VNFs and Service Chains).

10. Demo-1: Smart Insurance Providers as Key Requesters and Consumers of 5G Network Slices (Showcase by QualyCloud)

Demo-1's main contributors and organizers: ***QualyCloud***
From Service Providers (SPs) point of view, the "Smart Insurance" market is of high interest because it is an opportunity to create high value added services for SP's existing customers (or new customers) and can trigger technical drivers to evolve an

SP' infrastructures towards 5G arena in the way that can better monetize the SP's assets —thanks to the "Slicing" concept, and this transformation is bound to open up new business models—highly profitable and recurrent.
The 5G Network Slice "Factory" Service Providers are about to deploy in the coming years, is expected to deliver numerous Network Slice Types as described by 3GPP such as eMBB (SST 1), uRLLC (SST 2), mIoT (SST 3) which are the first standardized ones. Indeed, as stated in the Problem statement, in the IoT world, exiting technologies e.g. NB-IoT, LTE-M can partially answer this need. However, in Smart Insurance and infotainment (4K /8K, Augmented and /Mixed Reality), Autonomous Cars, Smart Factories, Smart Building / Smart Home, and others, 5G is expected to meet those eMBB, uRLLC, mIoT, (even other specified by the Service providers themselves) characteristics.
The ability of Service Providers (5G Slice Providers) to deliver those three key Slice Types and more in the future as enablers for such services or so to say "5G Slice as-a-Service (***5G Slice aaS***)" in terms of very large bandwidth and very low latency, will unlock some existing applications to new service models and pave the way for development of innovative applications we don't imagine today but will emerge in the future. 5G Slices are to be delivered by Service Providers in fulfilment of Slice Requests received from external slice requesters via self-care portals.
NOTE: Demo-1 of the overall PoC covered this aspect of Smart Insurance Providers as Key Requesters and Consumers of 5G Network Slices Delivery Services by Service Providers.

The BtoBtoC Scenario covered in Demo-1
The Smart Insurance platform collects data from IoT (connected car, e-health, connected home, …) in strict compliance of the insurance framework established around availability, security, privacy and usage of the information required in an insurance contract (i.e. European GDPR).
The e-call Smart Insurance use case illustrates a comprehensive application of the 5G network slices. In this case, all needed information (location, car status following an accident, pictures or video from dash cam, …) is categorized and shared per rules defined by the subscriber and their insurance contract. Parallel to that, a claim is automatically created on the platform with all relevant information. All the parties connected to the platform sharing confidential information related to the accident (contextual, technical and medical) are notified in order to attend to the emergency and solve the insurance claim.

Key Takeaways from Demo-1 of the Overall PoC

The Demo showed to the interactions of the Smart Insurance Platforms with

- This PoC illustrates the dynamic onboarding of new Parties to an existing digital ecosystem for Insurance.
- The lifecycle involves a series of APIs such as Ordering, Privacy, Party Onboarding, Agreement, SLA, etc. Such APIs are specified by TMForum (TMF 632 Party Management API, TMF 669 Party Role Management API, TMF 644 Privacy Management API, TMF 621 Trouble Ticket API) and the Telco industry and the verticals can leverage them in the 5G Slice services delivery to Slice consumers, even by adapting some of them if needed (very small overhead)
- The interaction with a 5G Network Slice Provider as Actor in the Digital ecosystem shows there is need for adapting current Service Provider's BSS to monetize Network Slice instances delivered to the partners in the Smart Insurance Digital ecosystem space
- The interaction with a 5G Network Slice Provider as Actor in the Digital ecosystem shows there might be a need for giving an active role to the partners consuming the Network Slices instances in terms of management of such services.
- This PoC covers a Digital ecosystem within Smart Insurance sector, but it can be generalized for any kind of digital ecosystem involving Parties with different roles and responsibilities, and consequently different access rights to users' data, while taking into consideration 5G Network Slice Providers as Provider of added value connectivity tailored to SLA requirements of a given Digital ecosystem. A generic Framework can be derived to be reused in any other Business context hence avoiding creating a Framework from scratch each time there is a need to launch a new project on PoC or deployment of the business scenarios
- The Use Cases demonstrated and can be reused in any Digital ecosystem that is Data-centric and where a 5G Network Slice Provider is involved are:
    - Create a new party and onboard it to an existing digital ecosystem to benefit from 5G capabilities
    - Manage a workflow with separation of roles and data that requires to be exchanged only between the rightly authorized Parties

- Manage Customer Experience (SLA violations, claims and trouble tickets) in proactive and predictive manner by *deploying a Framework for E2E Autonomic and Cognitive Service Assurance Closed Control Loop(s) that implement the ETSI GANA Framework in 5G Networks*

11. Demo-2: C-SON Evolution for 5G, Hybrid-SON Mappings to the ETSI GANA Model; Federation of GANA Knowledge Planes to achieve E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices—through a Real Implementation by Cellwize

Demo-2's main contributors and organizers: ***Cellwize, Orange, Incelligent, Altran and IPv6 Forum***
This Demo-2 of the PoC is focused on C-SON Evolution for 5G, Hybrid SON Mappings to the ETSI GANA Model, and Federation of GANA Knowledge Planes for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices through a Real Implementation achieved by a partner of the PoC Consortium. As such, Demo-2 covered the Autonomic (Closed-Loop) Service Assurance Use Case for 5G Network Slice(s) and the coverage in a Framework for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices achieved in Demo-2. The Demo presented and discussed the following:

- The GANA as enabler for Vendors to Implement Components required by Telecom Operators in implementing a Framework for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices and the Roadmap to achieving that goal.
- The value in the following ETSI documents: ETSI GANA Model (ETSI TS 103195-2); GANA Instantiation onto the 3GPP Backhaul and Core Network Architectures (ETSI TR 103 404); and GANA Instantiation onto the BroadBand Forum (BBF) Architecture Scenarios (ETSI TR 103 473).
- How Cellwize C-SON and its framework for policy control of D-SON implements the GANA Knowledge Plane for the RAN
- Cellwize provides an implementation of the GANA Knowledge Plane for the Backhaul of some degree and this software has been implemented as an integral part of Cellwize C-SON
- Demo of Cellwize C-SON GUI and its Provisioning GW as an Implementation case for the ETSI GANA MBTS (Model-Based Translation Service) Functional Component
- How GANA for the RAN is realized by Hybrid SON (C-SON (cognitive) complemented by D-SON in eNBs)
- How Cellwize C-SON and its framework for policy control of D-SON implements the GANA Knowledge Plane for the RAN
- Cellwize implementation of the GANA Knowledge Plane for the Backhaul of some degree and how this software has been implemented as an integral part of Cellwize C-SON
- Connected Cars Use Case and associated requirements on C-SON

The Demo-2 addressed various aspects **(A) to (I))** listed and highlighted below.
NOTE: A lot more details on the Capabilities of Cellwize's C-SON solution for 5G Slice Assurance are available in the Dem-2 Report and Slides accessible at [3] (https://ntechwiki.etsi.org/index.php?title=Accepted_PoC_proposals), and so readers are encouraged to access the Demo-2 Slides from [3].

A) Unifying/Integrating Architecture for ETSI GANA Knowledge Plane, SDN NFV, E2E Orchestration, Big-Data driven analytics for AMC (Autonomic Management & Control)

The Demo-2 also looked into how the industry can be guided by the Integrating Architecture for ETSI GANA Knowledge Plane, SDN NFV, E2E Orchestration, Big-Data driven analytics for AMC (Autonomic Management & Control) to further elaborate on the APIs (Application Programming Interfaces) necessitated by the Unified Architecture as well as Protocol Requirements for enabling GANA autonomics components in general to communicate with each other in driving autonomics in a particular architecture and environment. Figure 6 depicts such a Unified/Integration Architecture.
The industry can continue to elaborate implementation oriented details on Reference Points and associated API and Protocol Requirements defined in ETSI TS 103195-2 for the unifying (harmonizing) architecture for these complementary paradigms and contribute to the evolution of the standards in ETSI accordingly.
The community is therefore encouraged to continue to contribute solutions that address the APIs and Protocols Requirements, to ETSI or other SDOs/Fora such as TMForum, IETF, etc. Most of the APIs can be implemented as RESTFul interfaces and there are a lot of Open Source Tools and code that can be used to implement them, but OSS vendors, Orchestrator vendors, and SDN Controller vendors are also able to provide NorthBound Interfaces that can be used by the Knowledge Plane DEs to program network infrastructure as driven by the DEs' autonomics algorithms.

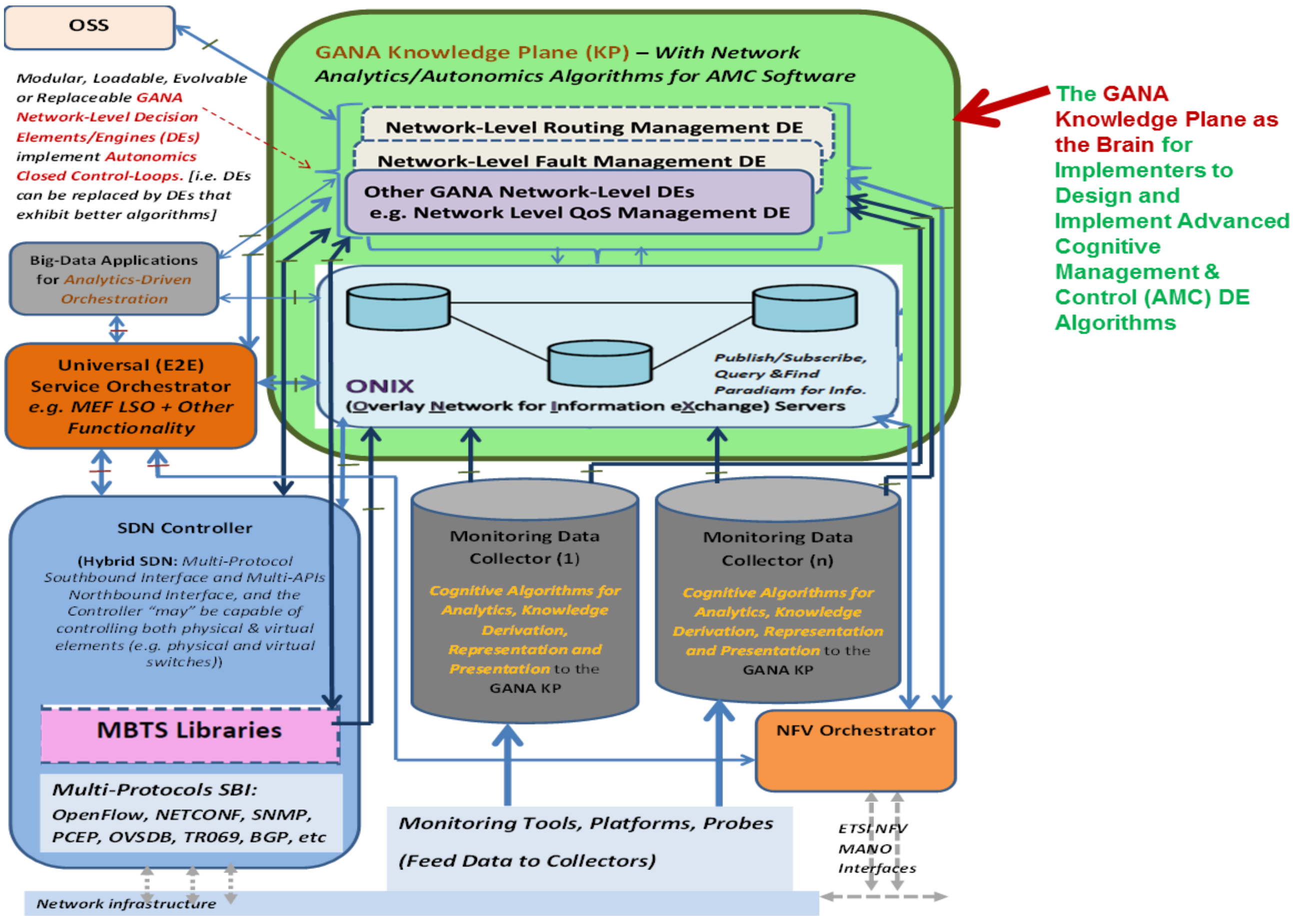


Figure 6: Unifying Architecture for ETSI GANA Knowledge Plane, SDN NFV, E2E Orchestration, Big-Data driven analytics for AMC (Autonomic Management & Control)

B) Architecture and Role of the GANA Knowledge Plane for the Transport Network (e.g. for Fronthaul and Backhaul) in Autonomic (Closed-Loop) Service Assurance for 5G Slices

In feeding data to the Knowledge Plane, various data sources indicated play a role, including Performance Management (PM), Fault-Management (FM) platforms, Telemetry data from Physical Network Functions (PNFs) and Virtual Network Functions (VNFs), Link Tapping and SPAN ports on switches that are used to build a TAP and SPAN Aggregation Network that feed data into tools like probes that are used for traffic analytics. Figure 7 depicts how a GANA Knowledge Plane for Transport Network can be implemented.

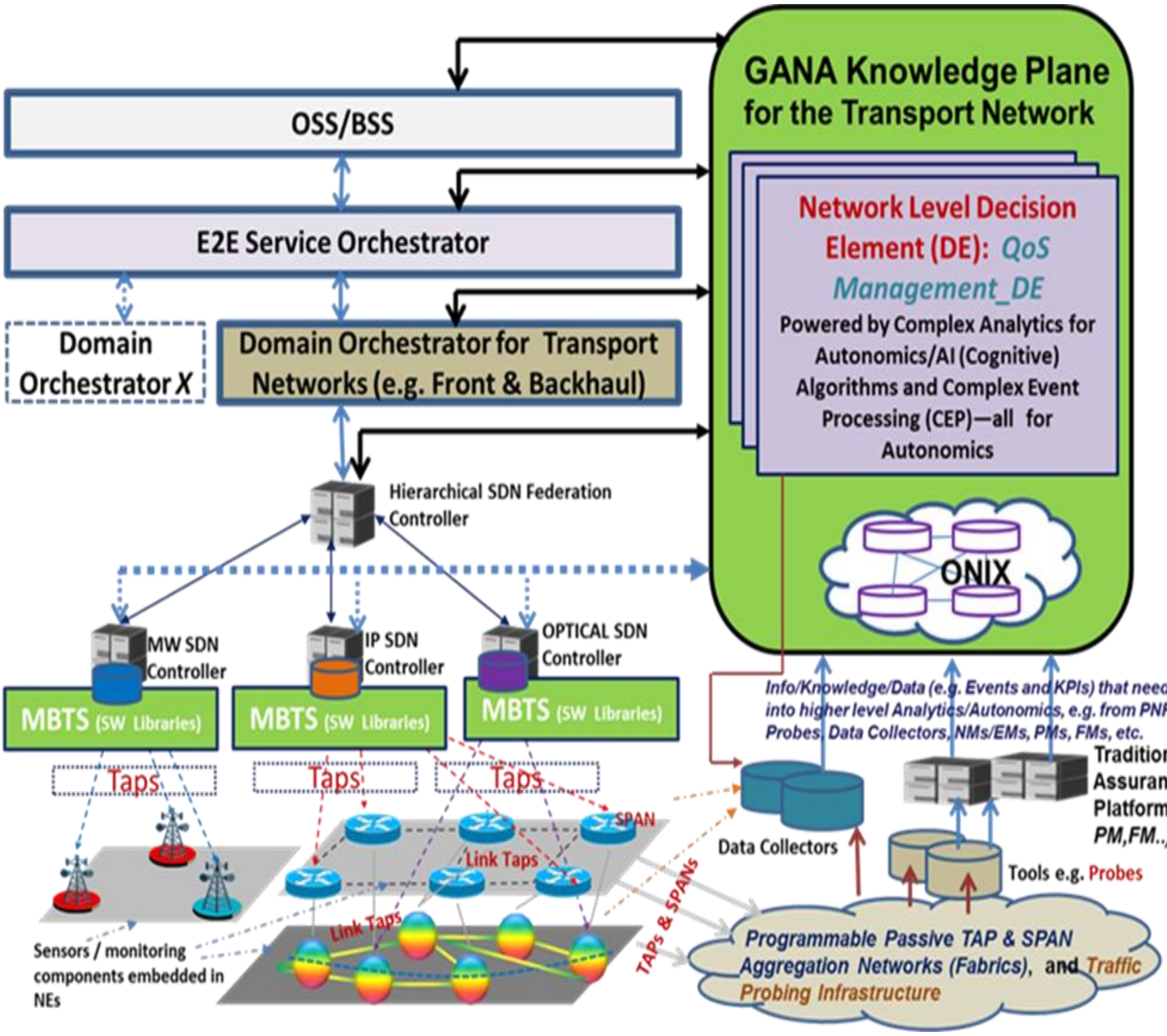


Figure 7: Illustration of how to implement and integrate a GANA Knowledge Plane for a particular network segment (e.g. a Transport Network) and integrate it with other management and control systems and with monitoring and service assurance related components

C) A Single Shared Instance of a GANA ONIX for the RAN GANA Knowledge Plane (C-SON), Transport Network GANA Knowledge Plane and Core Network GANA Knowledge Plane is Possible Scenario

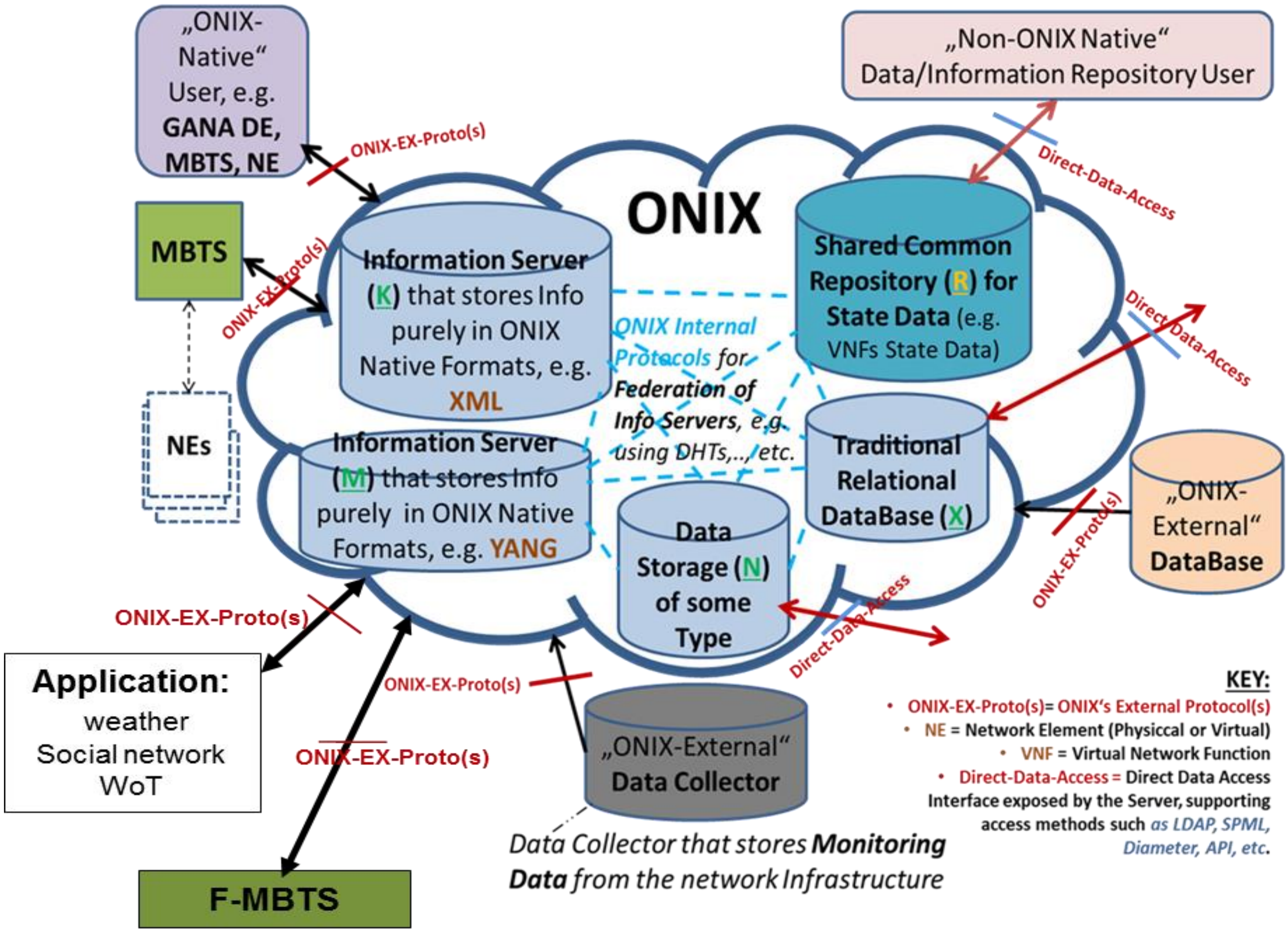


Figure 8: Illustration on how the ONIX systems can be implemented (more details on ONIX system concept are found in ETSI TS 103195-2)

ONIX as Real-Time Inventory for various types of information:

- Useful for Inventory awareness of changes over time, including Cache of Historical Decisions made by GANA Knowledge Plane DEs
- Near real time updates and extended auto-discovery, thanks to Publish/Subscribe Paradigm employed by ONIX
- Cognitive Algorithms running on some Information Servers in the management of certain information and knowledge makes ONIX a Cognitive inventory
- ONIX can be used for dynamic maintenance of network slice configurations
- Real-time topology map with context views of virtual networks, services & applications
- Relationship context between components & the network fabric & infrastructure Uses the network resources as the database of record due to their dynamic nature
- Provides a registration method used to discover & maintain services & resources

D). Hybrid-SON Mappings to the ETSI GANA Model

Figure 9 is an illustration of ***Hybrid-SON Model Mappings to the ETSI GANA Model*** and how GANA for the RAN is realized by Hybrid SON (C-SON (cognitive) complemented by D-SON in eNBs). The diagrams illustrate how the 3GPP Management Architecture maps to the ETSI GANA Model, e.g. how C-SON corresponds to a GANA Knowledge Plane (GANA level 4) for the RAN and how D-SON maps to GANA levels 2 and 3.

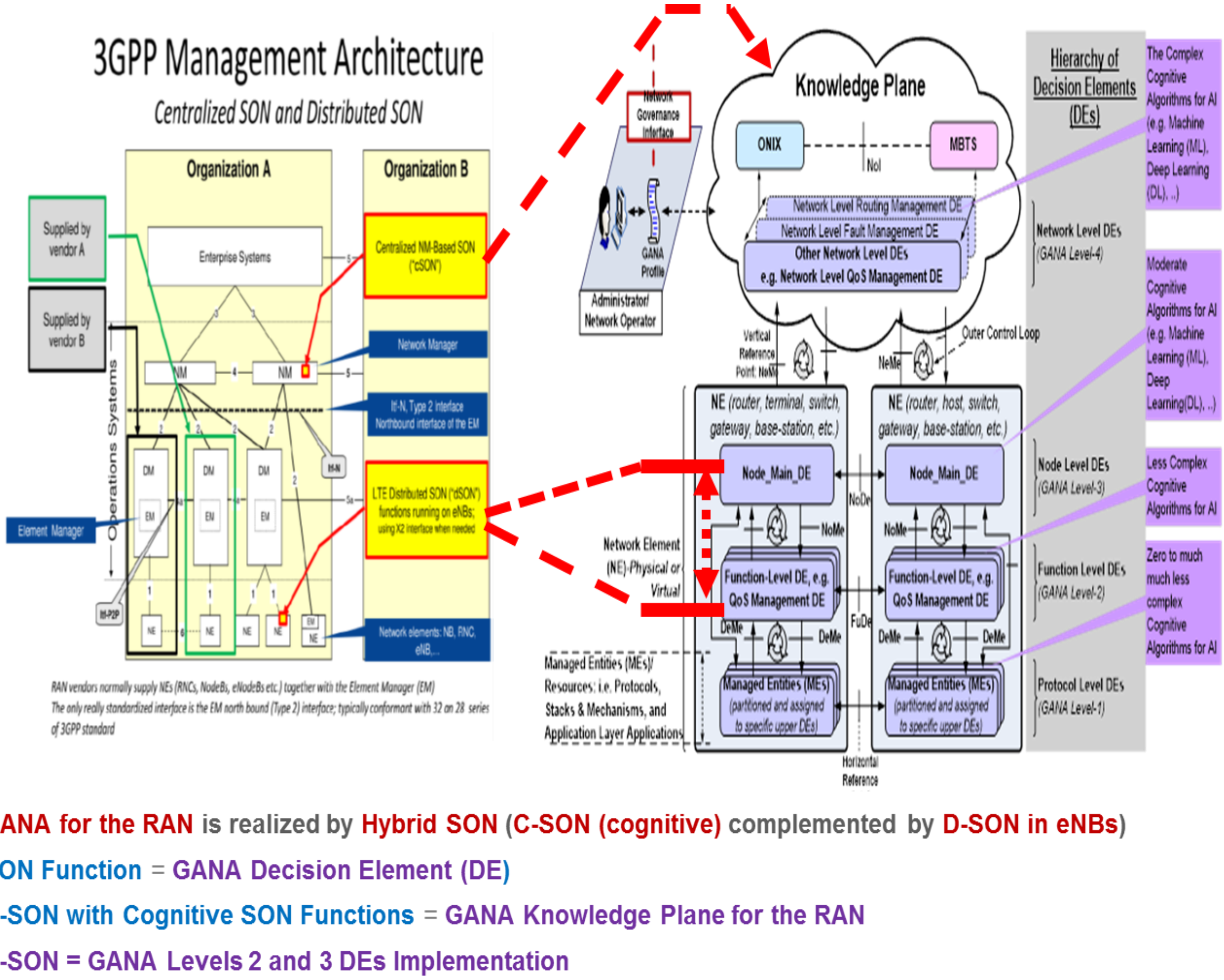


Figure 9: Hybrid-SON Model Mappings to the ETSI GANA Model

SON Function	Specialization of GANA DE as SON Function(s)
Plug & Play; CCO; ANR; RACH Optimization ; 0-Touch NR Rollout	Auto-Configuration-DE
Cell Degradation Management; COC	Fault-Management-DE; Resilience & Survivability-DE
ES (Energy Saving); Unified NSI Policy; Dual Connectivity; Carrier Aggregation	Auto-Configuration-DE
H00; Mobility Assurance & MRO	Mobility_Management_DE
LBO;MLB (Load Balancing & Traffic Steering); APO;	QoS_Management_DE

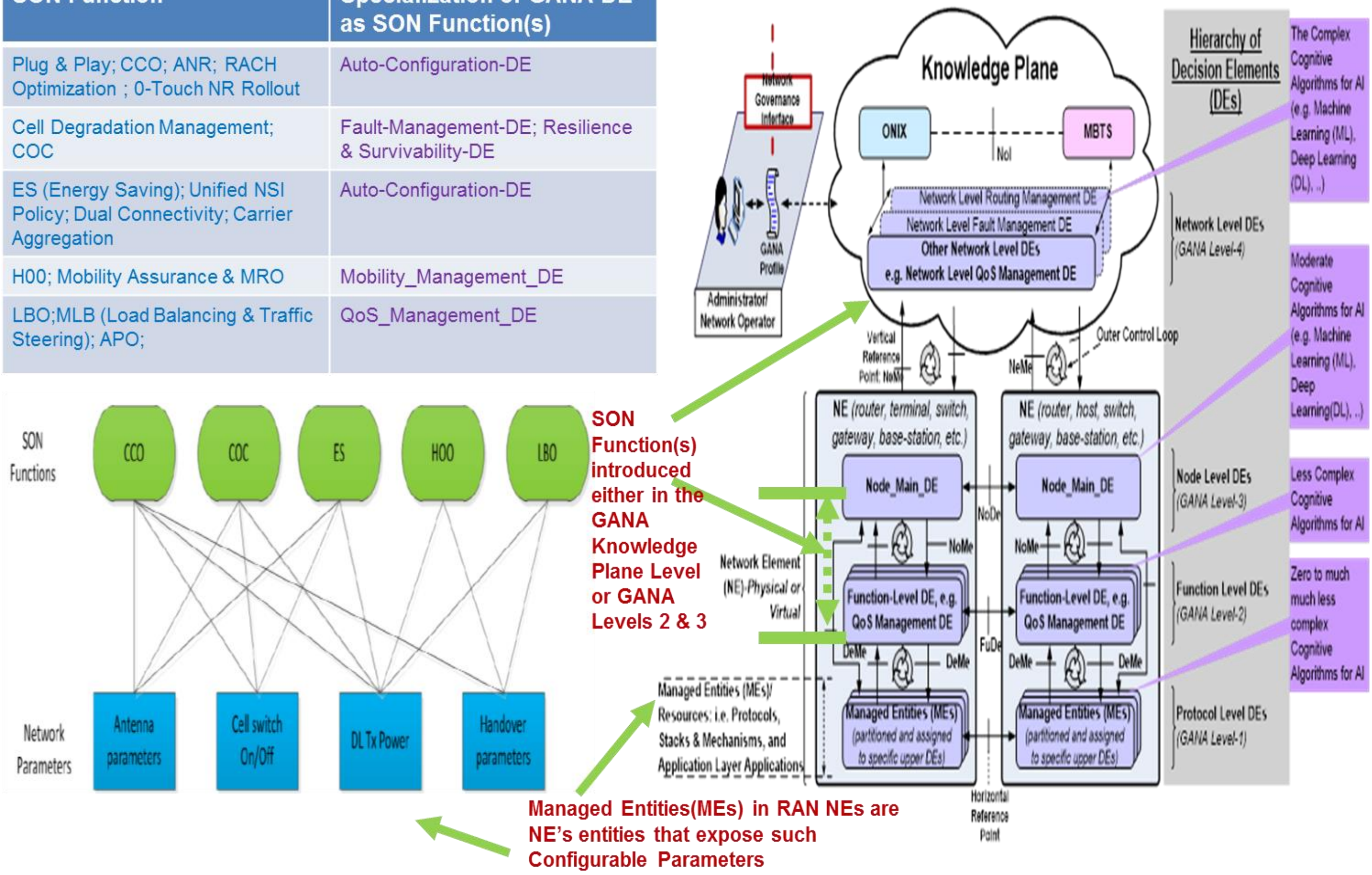


Figure 10: Illustration of SON Functions Mappings to the ETSI GANA Model, D-SON mapped to GANA Levels 2 & 3 DEs Implementation

The diagrams in Figure 10 and Figure 11 provide illustrate how Hybrid SON and the associated SON functions at C-SON level and at D-SON level implement the GANA for RAN.

	D-SON (GANA Levels 2&3)	C-SON (GANA Level 4)
Network View	Micro edge network view limited to the equipment vendor eNodeBs	Entire Network (bigger picture) view spanning across vendors and technologies
Data Accessibility	D-SON functions have access to a limited data set of the edge eNodeB and its local neighbourhood	C-SON has access to a wide data set covering all node types (eNodeB, NodeB and BTS) and external data sources (e.g., analytics and crowdsourcing)
Operational Restrictions	D-SON functions operate with knowledge limited to local surrounding environment and only control own node. Local execution at the network edge.	C-SON functions operate with complete visibility of all nodes and control the entire cluster. Centralized execution at the OSS level.
Multi-Vendor	D-SON only works on own equipment	complete Multi-Vendor support
Cross Technology	4G only (*) Proprietary D-SON solutions exist in 3G (ANR, Scrambling Code collision detection)	2G, 3G, 4G
Customization flexibility	Proprietary "black-box" functions with limited (complex) flexibility	High degree of flexibility, simple to adapt to MNO policies
HetNet Orchestration	Islands of D-SON functions	Entire network orchestration & coordination covering both C-SON and D-SON functions across vendors, technologies and network layers
Data Correlation	limited to eNodB data	Multi-dimensional data
Cycle time	Short cycle time (mSec) - Real Time use-cases	longer cycle time (min) - Near Real Time use-cases
Performance Load and Coordination	UEs required to read CGI of neighbouring cells, hence can impact inter-node communication (LTE X2 I/F). Coordination overhead increases as the network is densified creating possibility of inconsistencies/conflicts (e.g., PCI confusion)	C-SON collects centralized information through existing North Bound Interfaces (NBI) and has no impact UE performances. High degree of coordination across a wide geographic area including D-SON islands.
CCO (Antenna tilt Optimization)	Not available	Multi-band & technologies CCO supported
PCI	PCI collision detection (only)	PCI detection and automatic correction
Policy enforcement	Not available	Seamless policy enforcement and consistency management
Inter-RAT	Not available (e.g., ANR IRAT)	Cross technology support LTE to/from UMTS & GSM
RACH Optimization	Not available (RSI & Cell Range)	RSI & Cell Range optimization use-cases supported
Integrated into eNB RRM activities (layer3)	Utilized by D-SON MLB & MRO edge functions	Infeasible for a centralized architecture
Swap/Rehoming process	limited support as D-SON functions utilize 3GPP CGI as the unique identifier of each node	C-SON flexibility allows for MNOs customs node identifier to be utilized for equipment swap or rehoming procedures
Cell Outage Detection and Compensation (CODC)	ANR based compensation	Cluster level ANR and CCO based compensation with embedded rollback mechanism triggered when outage has seized

Figure 11: GANA Knowledge Plane Level Autonomics (C-SON) vs GANA Levels 2&3 Lower Level Autonomics (D-SON)

E) Cellwize 5G RAN Service Assurance Workflow for C-SON (GANA KP for RAN)

Demo-2 Slides available (accessible) at [3] (https://ntechwiki.etsi.org/index.php?title=Accepted_PoC_proposals) provide a lot more details on the Cellwize C-SON for 5G Solution and other Cellwize Capabilities.

Figure 12 provides more details on the covered aspects in this Demo-2 against further targets. This also serves as illustration of Cellwize 5G RAN Service Assurance Workflow for C-SON (GANA KP for RAN).

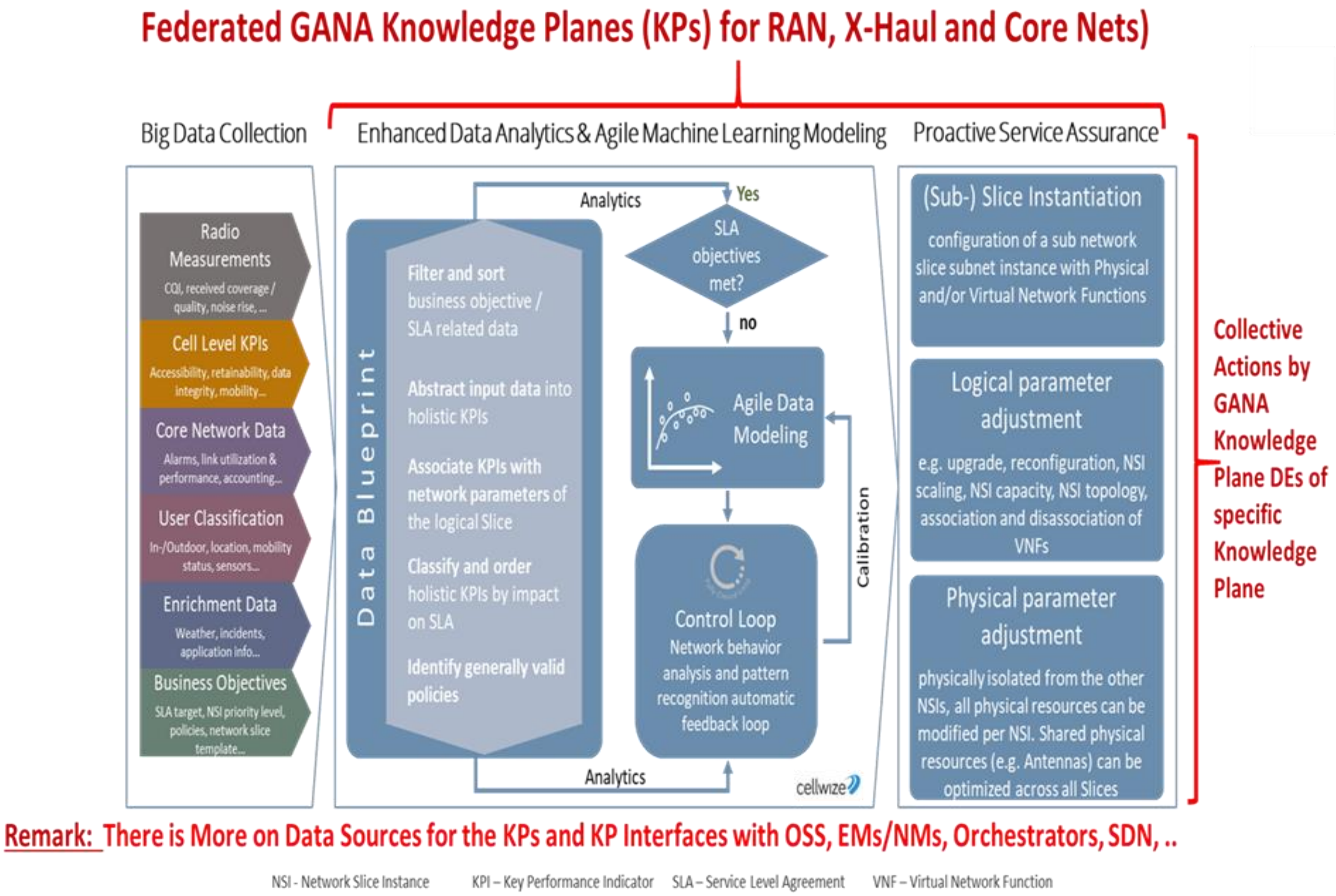
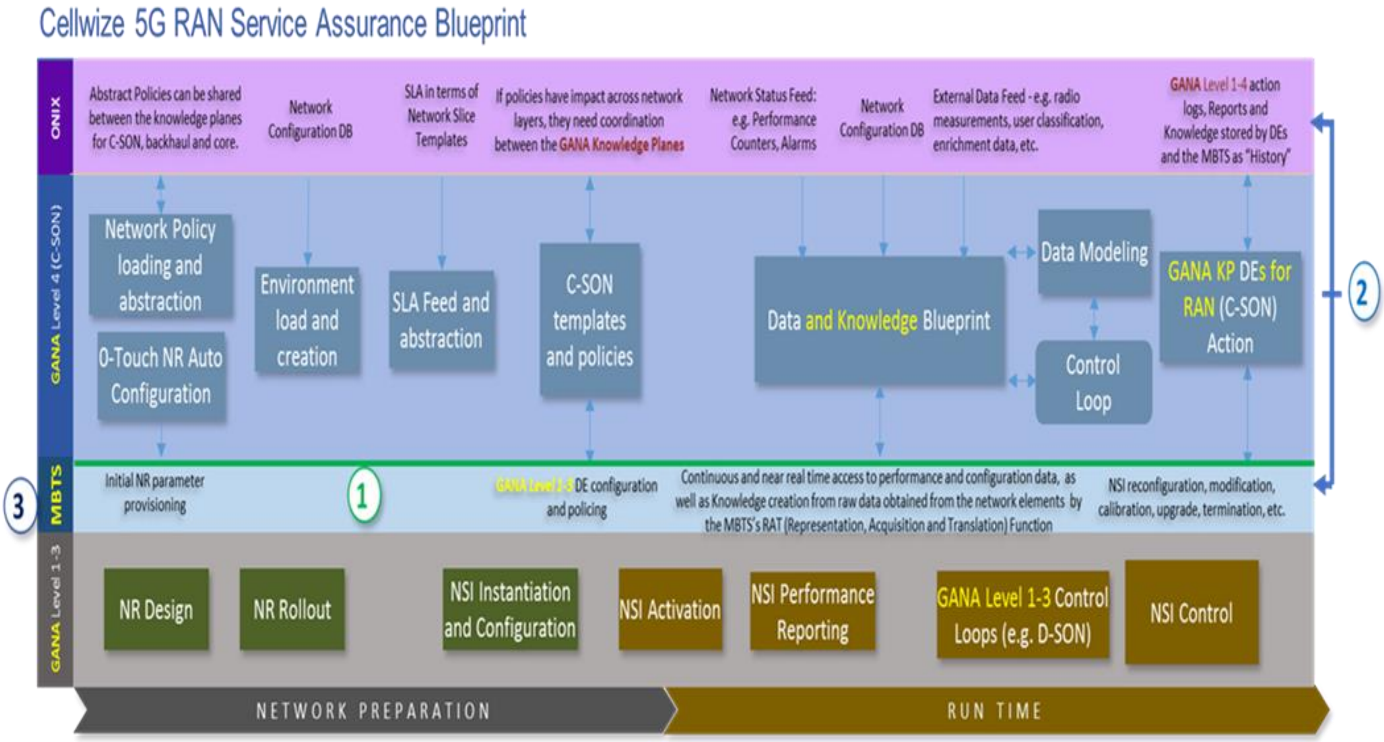


Figure 12: Cellwize 5G RAN Service Assurance Workflow for C-SON (GANA KP for RAN)

F) Cellwize Provisioning GW as an Implementation case for the ETSI GANA MBTS (Model-Based Translation Service) Functional Component

The following diagram (Figure 13) illustrates the Cellwize 5G RAN Service Assurance Blueprint. It also illustrates how the GANA components are implemented by the Cellwize Solution Blueprint, with mappings of the GANA Decision-making levels (including Knowledge Plane) and their roles in fulfillment of autonomic service assurance of a Network Slice Instance (NSI). On the interfaces between ONIX, C-SON and the MBTS characterizations on what is communicated on the interfaces are provided. The implementation shows how the Cellwize Provisioning Gateway (GW) is an implementation for the MBTS function. More details on the Cellwize Service Assurance Coverage Map for 5G can be found in the slides available at [3].



Remarks:

(1) MBTS Interface with DEs must be a strong interface for continuous real time status and configuration knowledge streaming from the MBTS to DEs and immediate implementation of slice modification/upgrade actions issued by DEs towards NEs.

(2) The MBTS stores knowledge from network raw data into ONIX, while streaming it to the DEs in real-time. MBTS may also pull Data/Info of interest from ONIX (e.g. configuration data available through ONIX)

(3) The Cellwize provisioning gateway represents an implementation of the GANA MBTS for the RAN that can be opened for other Knowledge Plane service providers

Figure 13: Cellwize 5G RAN Service Assurance Blueprint as Illustration of Implementation case for the GANA for RAN

The following diagram (Figure 14) illustrates the Cellwize Provisioning GW as an Implementation case for the ETSI GANA MBTS (Model-Based Translation Service) Functional Component, as well as a characterization of the interactions on the interfaces of the key components of relevance to the Provisioning GW. It shows how the Cellwize C-SON Provisioning Interface architecture is built to translate vendor agnostic commands to vendor specific language (an aspect of MBTS functionality).

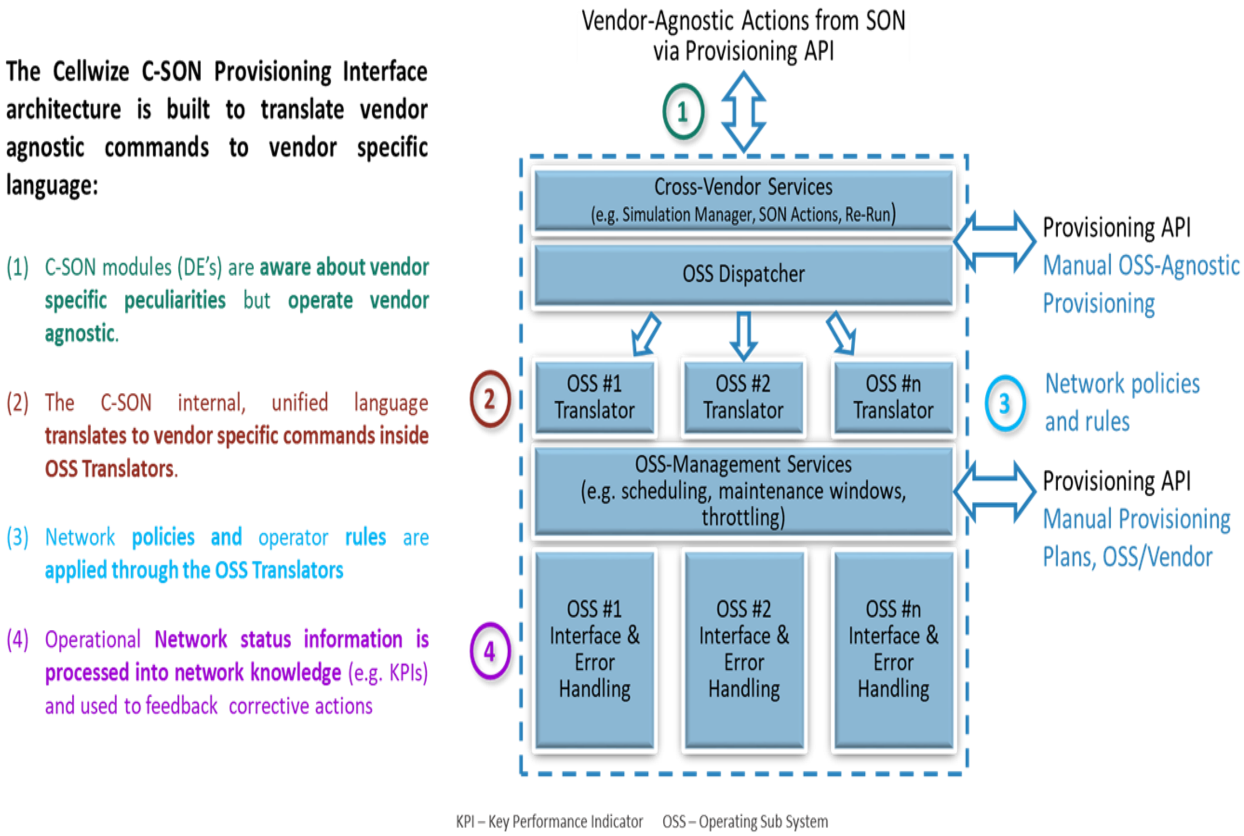


Figure 14: Cellwize Provisioning GW Mapping to GANA MBTS Function

The following diagram (Figure 15) illustrates the current mapping and required evolution of the Cellwize Provisioning Gateway (GW) towards MBTS for RAN.

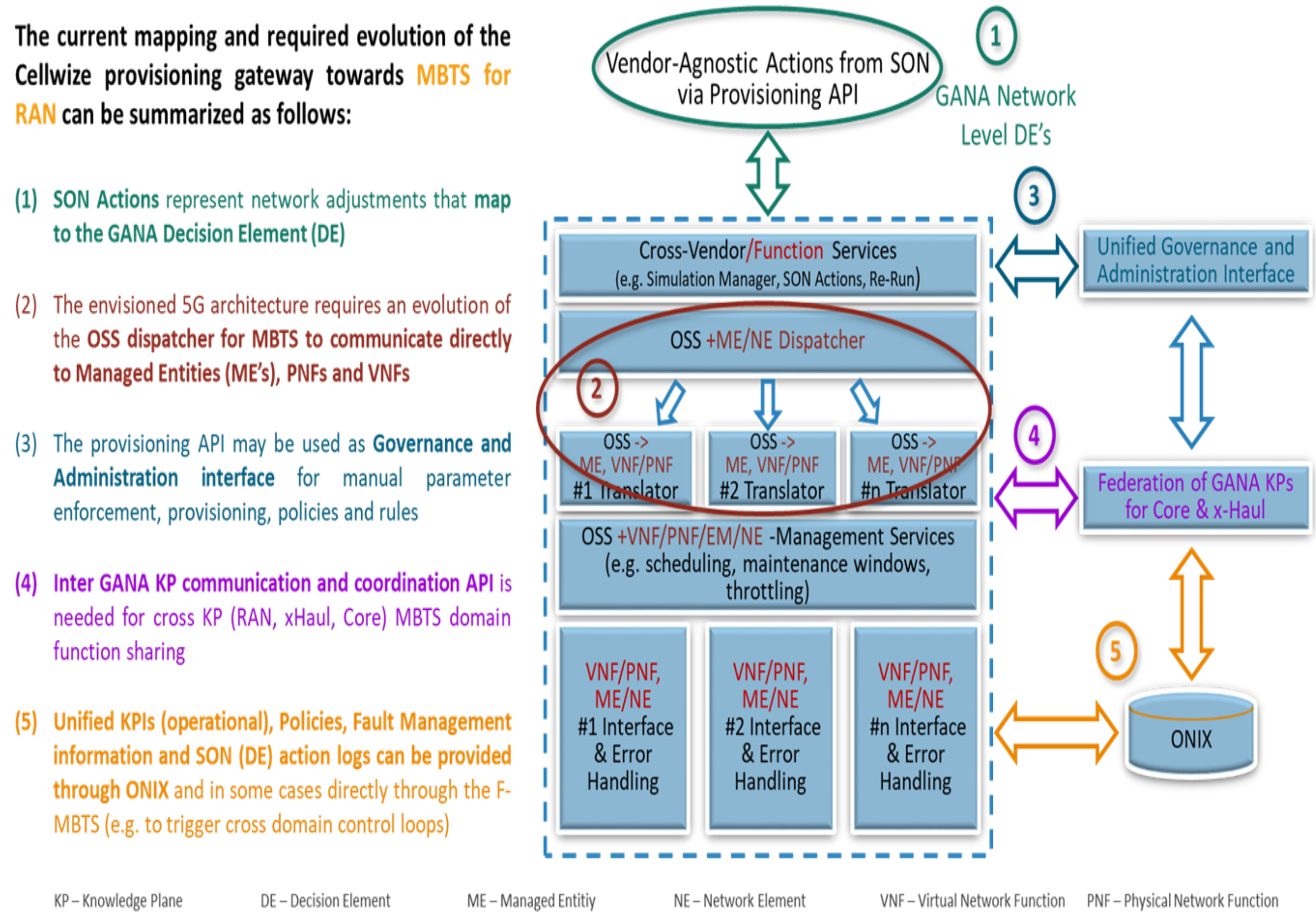


Figure 15: Cellwize Provisioning GW Mapping to the GANA MBTS for RAN

G) ONAP Mapping MBTS for 5G Slice Service Assurance

The following diagram (Figure 16) illustrates an ONAP mapping (usage of ONAP components) in the realization of an MBTS, taking into consideration, Big Data Collection, Enhanced Data Analytics & Agile Machine Learning Modeling, and Proactive Slice Optimization aspects.

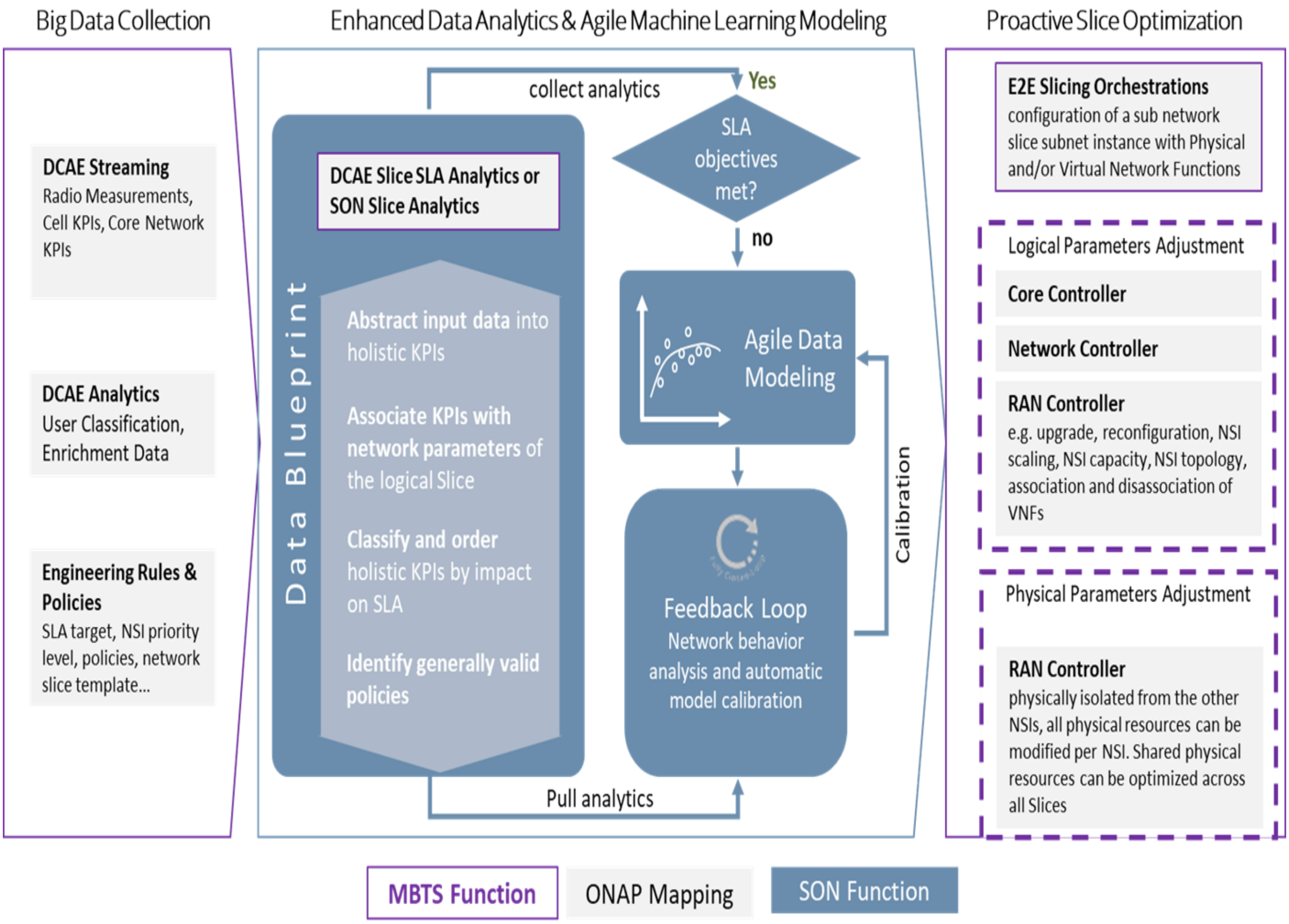


Figure 16: ONAP Mapping MBTS for 5G Slice Service Assurance

H) Cellwize Solutions and Case Study on 5G Slice Autonomic (Closed-Loop) Service Assurance Use Cases

The following diagram (Figure 17) illustrates the Connectivity Ecosystem for Connected Cars in which Cellwize has solutions that address various aspects of relevance to autonomic service assurance of 5G Network Slices. More details on the Cellwize Cellwize solutions can be found in the slides available at [3].

The 5G Slice Autonomic (Closed-Loop) Service Assurance Use Cases demonstrated in this Demo-**2** are:

- Connected Cars Use Case and associated requirements on C-SON

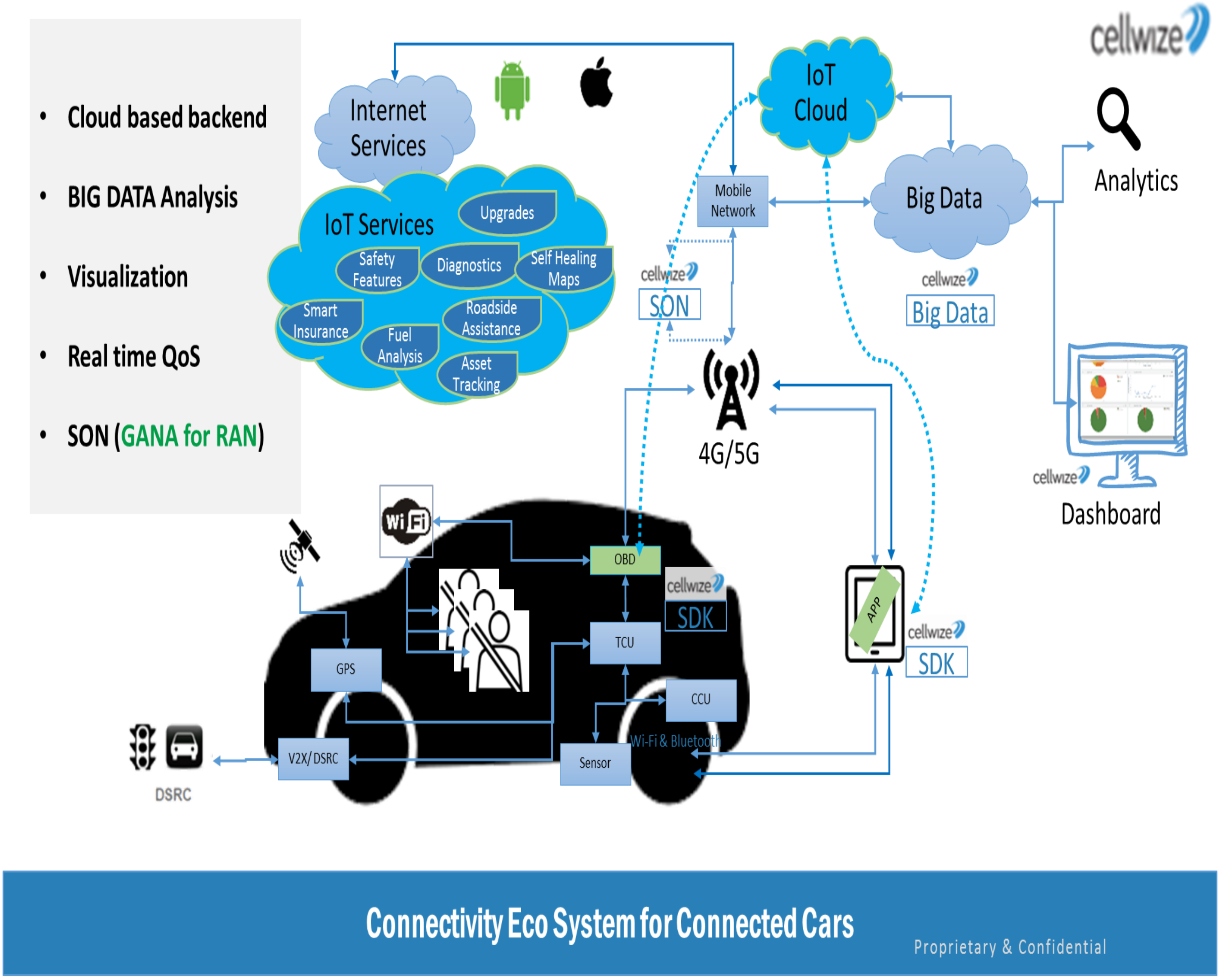


Figure 17: Connectivity Eco System for Connected Cars

- Manage Customer Experience (SLA violations, claims and trouble tickets) in proactive and predictive manner by tacking advantages from Autonomic and Cognitive Service Assurance Closed Control Loop(s) that implement the ETSI GANA Framework in 5G Network
- Describe Standards Gaps being revealed in attempting to specify a Framework for E2E Autonomic (Closed Loop) Service Assurance for 5G Network Slices. This is the case when considering Federation of GANA Knowledge Planes (KPs) for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices through the interworking of a GANA Knowledge Plane for RAN (realized through Centralized SON (Self-Organizing Networks) with cognitive SON functions), GANA Knowledge Plane for the Transport Network (e.g. x-haul/Backhaul) and a GANA Knowledge Plane for the Core Network, for correlated assurance of RAN Subnetwork Slices, Backhaul Subnetwork Slices and Core Network Subnetwork Slices

The following diagram (Figure 18) illustrates the Cellwize's C-SON capabilities for 5G Network Slice Assurance, as well as the interactions with other key Functional Blocks of relevance to E2E Autonomic Service Assurance of 5G Network Slices, while giving particular attention to 5G C-SON Abstraction Layer. More details on this can be found in the slides available at [3].

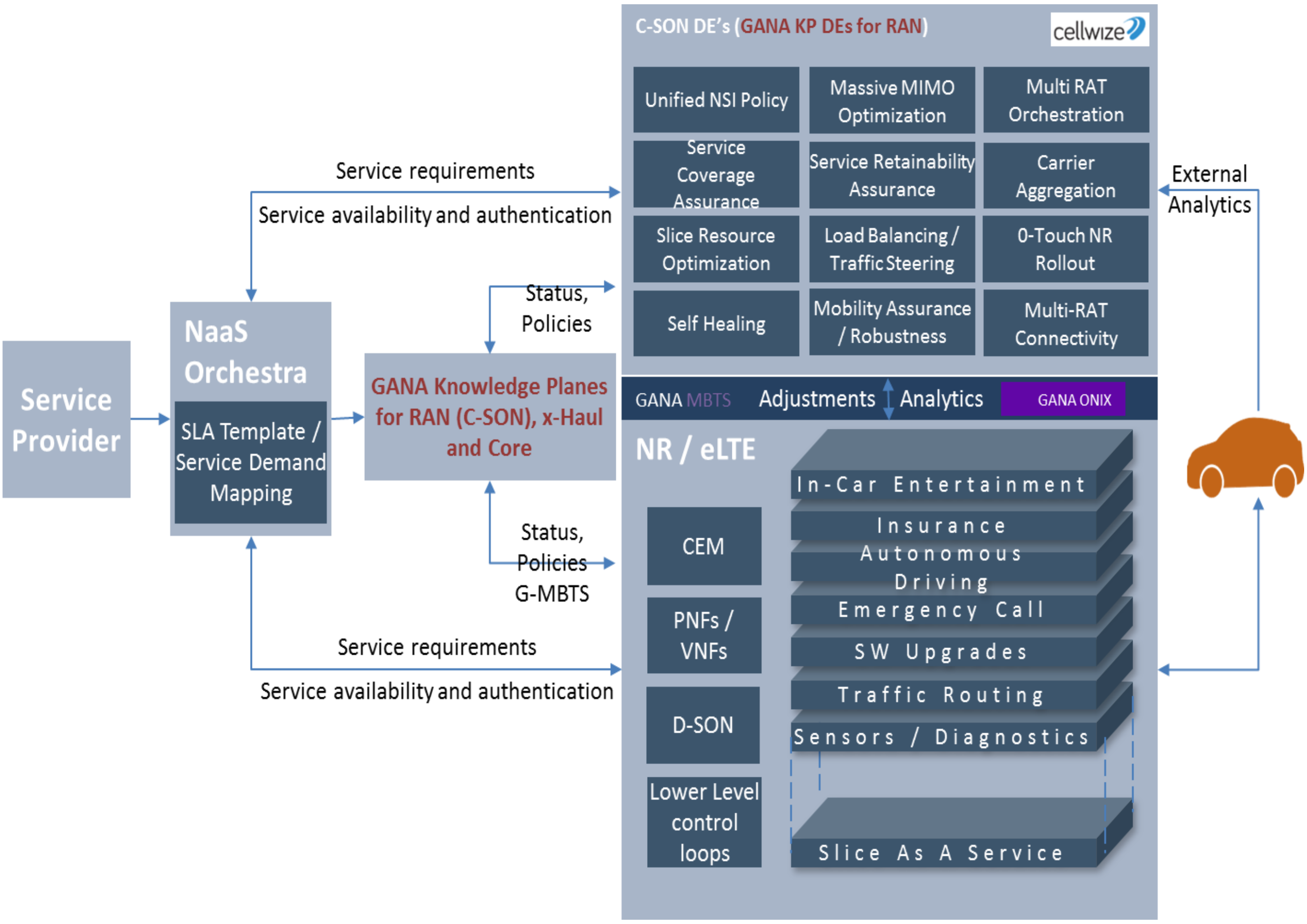


Figure 18: 5G C-SON Abstraction Layer

The following diagram (Figure 19) is an illustration of IoT Slice Lifecycle for Connected Cars, and Cellwize solution coverage. More details on this can be found in the slides available at [3].

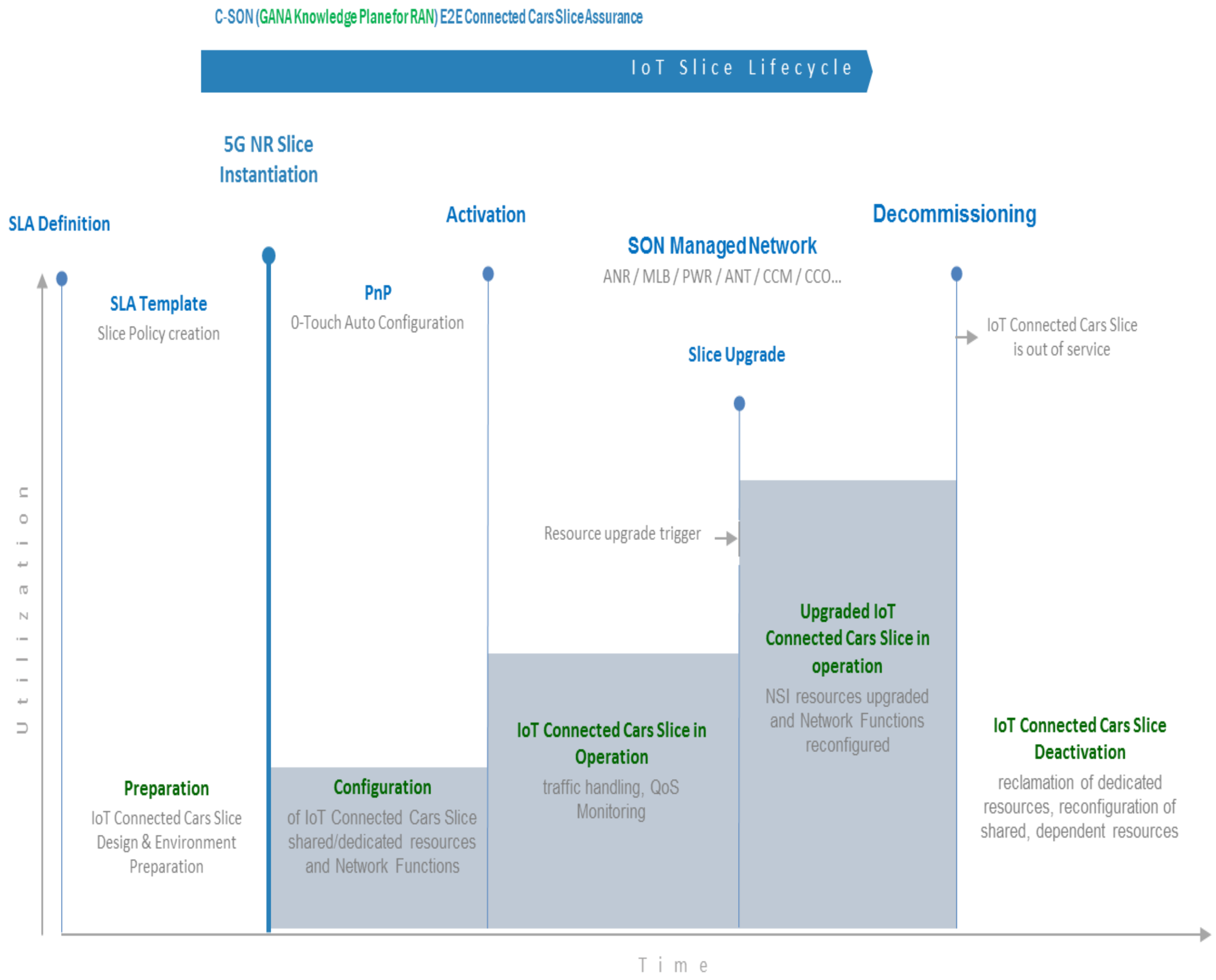


Figure 19: IoT Slice Lifecycle for Connected Cars

The following diagram (Figure 20) is an illustration of Connected Car Service Assurance use case for 5G network slice management and optimization, and the coverage by Cellwize Solution. More details on this can be found in the slides available at [3].

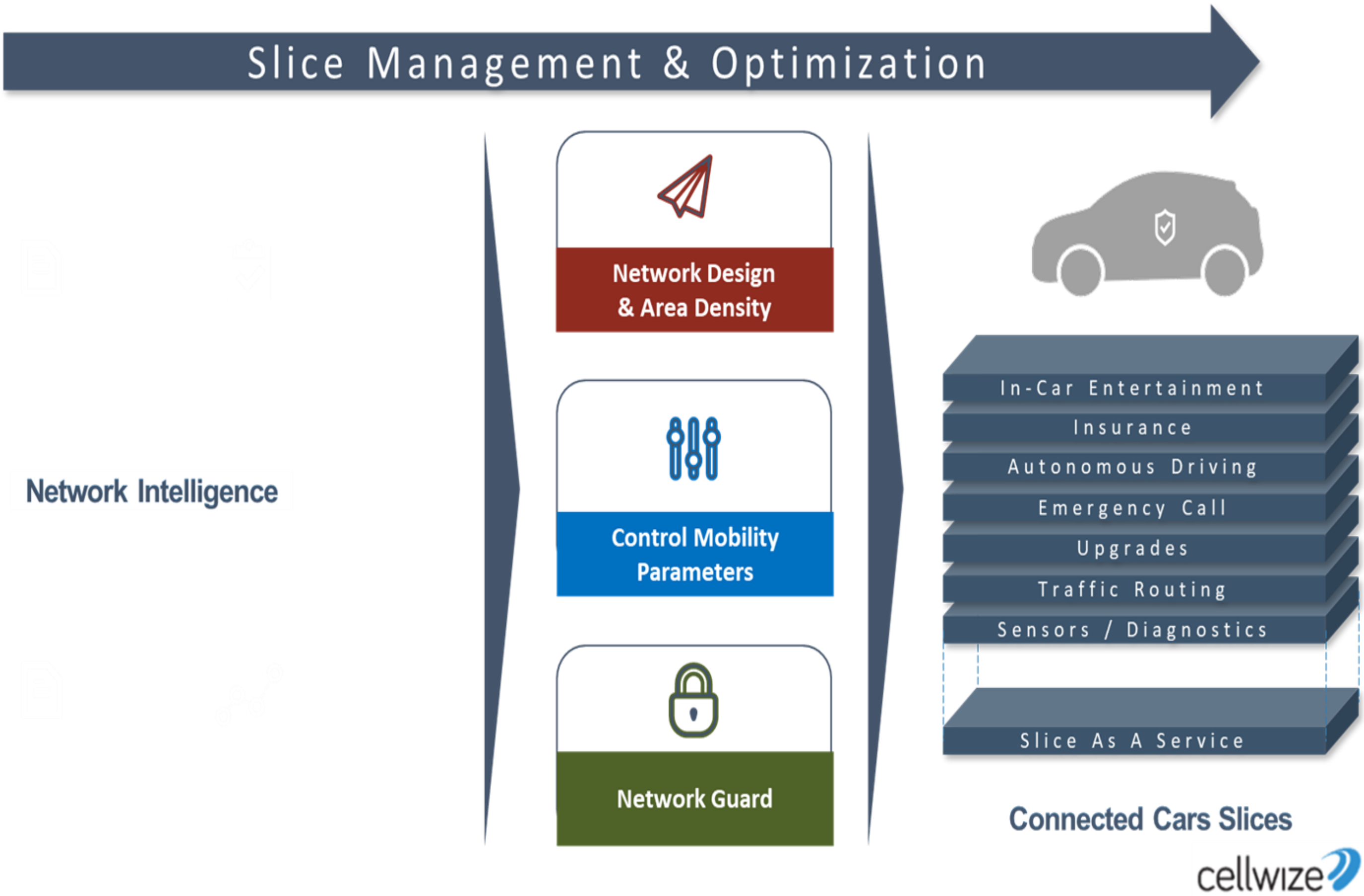
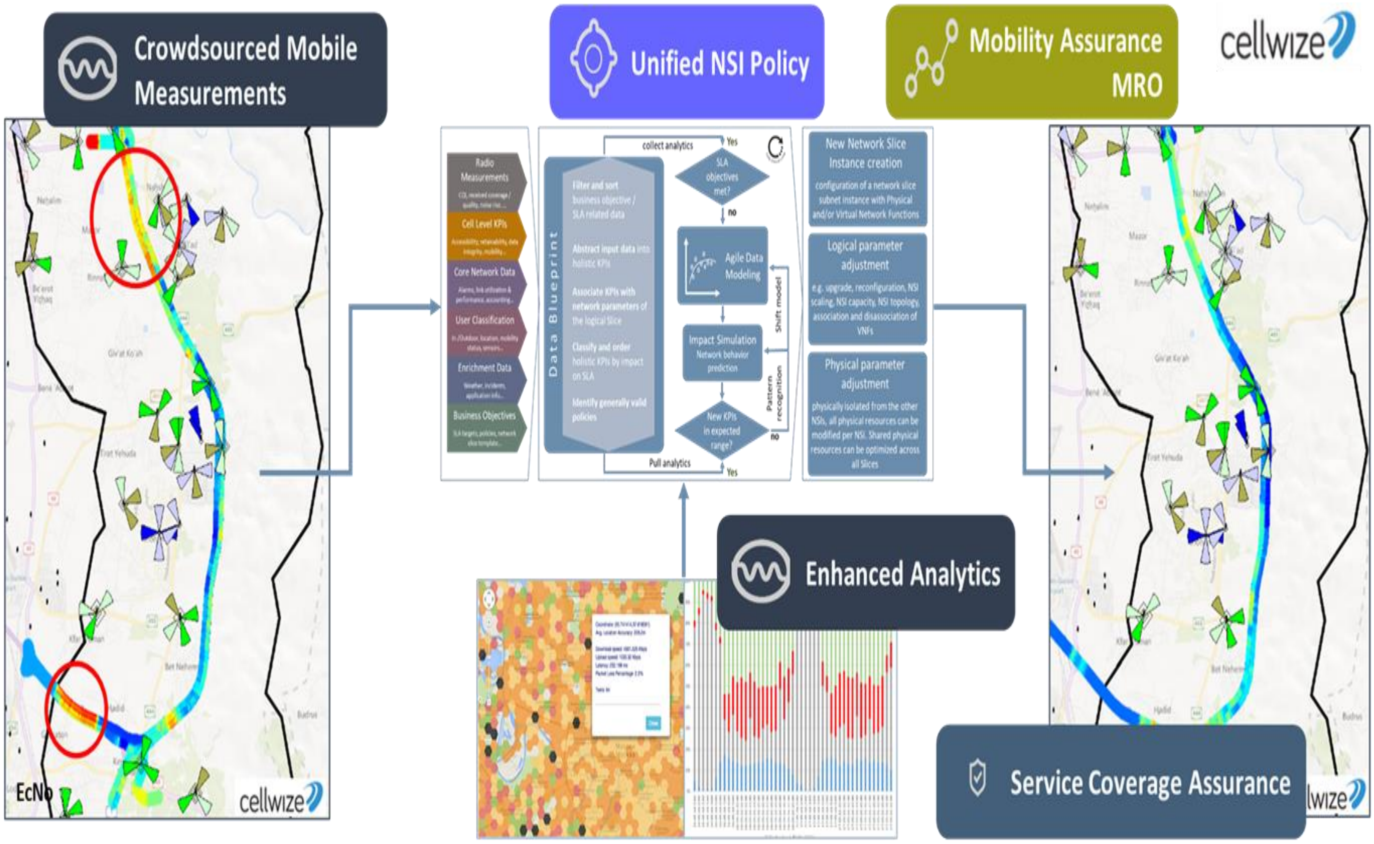


Figure 20: Connected Car Service Assurance use case for 5G network slice management and optimization

The following diagram (Figure 21) is an illustration of Cellwize Solution for Connected Cars (a Highway Use Case). More details on this can be found in the slides available at [3].



Demanded NSI Service Level performance can be assured through:

- The orchestration of enhanced big data analytics in combination with immediate access to unified policies and real time provisioning of NSI modification actions
- The Federation of GANA Knowledge Planes (KPs) for Radio Access-, X-Haul- and Core Networks, and strong interfaces with OSS, EMs/NMs, Orchestrators, SDN, .. for prompt access to knowledge for the KPs

Figure 21: Cellwize Solution for Connected Cars| Highway Use Case

I) C-SON –ONAP Architecture, using ONAP Components to implement GANA Knowledge Planes (Advanced ONAP for implementing ETSI GANA Standard Requirements)

Demo-2 Slides available at [3] (https://ntechwiki.etsi.org/index.php?title=Accepted_PoC_proposals) provide insights on this topic. However, White Paper No.2 of this ETSI 5G PoC provides more up to date information and details on this subject, and so readers are encouraged the White Paper No.2 as well.

Key Takeaways from Demo-2 of the Overall PoC

The following are the key takeaways from Demo-2:

- The Service Assurance for Network Slices should be achieved through Closed-Loop (Autonomic) Service Assurance of the E2E Network Slices by means of a Federation of Autonomic Service Assurance Components that collectively work together in an E2E fashion to deliver Network Slices Assurance and adaptive network resource programming across the network segments delivering the aggregate Network Slices, e.g. across Access Networks, x-Haul (Fronthaul and Backhaul) and Core Networks. SON (Self-Organizing Network) functions for the 5G RANs should interwork with GANA components such as GANA Knowledge Plane components to deliver E2E Autonomic Service Assurance of Network Slices for Self-* features for network slices, such as *Self-Optimization and Self-Healing of Network Slices*. For Telecom Operators, all this constitutes a *Framework for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices* that should be implemented by Operators
- Cellwize C-SON and its framework for policy control of D-SON implements the ETSI GANA (Generic Autonomic Network Architecture) Knowledge Plane for the RAN, whereby a D-*SON Function* is a *GANA Decision Element (DE)* and *C-SON with Cognitive SON Functions is GANA Knowledge Plane for the RAN*
- **Cellwize provides an implementation of the GANA Knowledge Plane for the Backhaul to some degree**
- GANA for the RAN is realized by Hybrid SON (C-SON (cognitive) complemented by D-SON in eNBs)
- The Cellwize C-SON Implementation Opens a Door and **Opportunity Towards a Specification/Standardization of an MBTS (*Model-Based-Translation Service as a mediation service between Knowledge Plane and NEs)* for RAN (an MBTS that also covers 5G)**
- **The GANA model empowers Autonomic (Closed-Loops) Service Assurance for 5G Network Slices**
- This ETSI 5G PoC is clarifying the Required Carriers'(Operators') ***Framework for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices*** → E2E Autonomic Slice Assurance shall be achievable through the Federation of GANA Knowledge Planes for RAN (C-SON), Front-/Backhaul and 3GPP Core Network, complemented by lower level autonomics, for Multi-domain state correlation and programming by the GANA KPs (RAN, DC, MEC, Backhaul, Core Network)
- There is a **need for Integration/Convergence of Autonomic Service Assurance with Orchestrated Assurance** in the Carrier/Operator's Environment
- Further Study on how to exploit and evolve **ONAP Components to address ETSI GANA Requirements** should now be triggered and contributions to ONAP and other **Open Source Projects like TIP (Telecom Infra Project) and BBF CloudCO and Open BroadBand** should now be launched based on Liaisons between ETSI NTECH AFI WG and TIP, ONAP and BBF. ETSI NTECH AFI WG has established Liaisons with ONAP, TIP and BBF in order to seek collaboration on this 5G PoC and its various planned Demo phases.
- We are **calling upon the IPv6 Community to Showcase in this PoC and Discuss more on IPv6 Features that play a role in Autonomic Management and Service Assurance in 5G**, and IPv6 expectations in 5G Traffic Flows and QoS Tuning
- **Hybrid-SON Model (Combining C-SON and D-SON) is an illustration of ETSI GANA model for the RAN**

12. ETSI-GANA Model as key Enabler for 5G: High Level Design Principle

The AFI Working Group in ETSI's INT Technical Committee (TC) (previously hosted in ETSI TC NTECH), as the leading group in the standardization landscape for Autonomic / Cognitive Management & Control of Networks and Services, has a comprehensive work programme which comprises deliverables on: a reference model for a Generic Autonomic Network Architecture (GANA); an implementation guide for the GANA reference model; and autonomics-enabled implementation-oriented network architectures and their associated management and control architectures that are a result of GANA instantiations onto various reference network architectures and their associated management and control architectures defined by standardization organizations such as 3GPP, BBF, IEEE, ITU-T and other Standards Developing Organizations (SDOs). The following ETSI White Paper summarizes the activities and deliverables:

http://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp16_gana_Ed1_20161011.pdf

Indeed, ETSI TC INT AFI WG has made significant progress in developing standards that prescribe methods and mechanisms for introducing "intelligence" in the management and control operations of networks and services and on how to operationalize GANA. Namely the application of the "Autonomics" paradigm, with the goal of prescribing design and operational principles for self-managing and self-adaptive networks that enable to achieve OPEX reduction through Autonomic & Cognitive Fulfillment & Service Assurance(see http://appledoreresearch.com/product/closed-loop-automation-new-role-assurance-research-note/)

Other benefits "Autonomics" brings to Network Operators such as creation of new revenue stream in 5G arena where Autonomics and specifically GANA can be key Enabler: http://www.iwpc.org/workshops/2016/2016-06-DT/agenda.html

More Background Details on the ETSI TC-INT/AFI WG 5G Network Slicing PoC (with Autonomic (Closed-Loop) Service Assurance for Slices) and 5G PoCs landscape:

After the first 5G related standardization round (NGMN's 5G White Paper, E2E 5G Architecture, SCT), 3GPP (R14, R15) efforts that took off, ITU efforts on 5G that took off, and the initial 5G roadmaps that were laid out by the diverse players in 5G, an acceleration process was undertaken in 2017. Most of key Mobile Operators are pushing things this way by announcing aggressive roadmaps and seizing key events (sport related) to use them as 5G playgrounds where all 5G players try to deliver their best products and solutions and to demonstrate the first benefit 5G brings and the huge promises and perspectives on how 5G will nicely complement 4G. This acceleration will pave the way for the commercial deployment of 5G.

From Testing & Trialing side, various initiatives have been launched and there is a need for harmonization in terms of methodology, assessment approaches, interoperability, KPIs consolidation as a foundation to facilitate this move. This is the reason why this ETSI INT 5G Network Slicing PoC aims at collaborating and liaising with other industry driven 5G PoCs initiatives but not limited to initiatives such as NGMN 5G_TTI, TMForum "5G Service Operations" Catalyst, and BroadBand Forum (BBF) 5G related PoCs programs.

13. Federation of GANA Knowledge Planes to achieve E2E Autonomic (Closed-Loop) Service Assurance across various network segments/domains

E2E Autonomic Service Assurance of E2E Network Services (including 5G Network Slices) shall be achievable through the **Federation of GANA Knowledge Planes (KPs) for specific network segments/domains**, and **complemented by lower level autonomics in Network Functions(NFs),** for achieving "Holistic Multi-Domain State Correlation and adaptive resources programming" by the **GANA KPs** for **Access**, **Backhaul**, and **Core Networks** (as illustrated below (by figures 22 and 23)**).**
The scope of Federation of Knowledge Planes may be extended to cover other domains beyond the core network, such as a Data Center Network hosting some Telco-Cloud Network Functions or even IT Applications**.** Service Providers seek to deploy such a **Framework for E2E Autonomic (Closed-Loop) Service Assurance for Network Services** as illustrated below and in ETSI TR 103 404 and the Reports available at [3].
ETSI TS 103 195-2 provides guiding principles that help implementers to implement Federation of GANA Knowledge Planes across multiple domains (including administrative domains). ETSI TR 103 404 and ETSI TR 103 473 provide insights on Federation of GANA Knowledge Planes for various network domains/segments that are very useful for implementers. For more information and PoC results and requirements on Federation of GANA Knowledge Planes for E2E Autonomic (Closed-Loop) Service Assurance across the various network segments/domains readers should also refer to [3][4].

The figure 23 presents the illustration that E2E Autonomic Service Assurance shall be achievable through the ***Federation of GANA Knowledge Planes (KPs) for specific network segments and domains***, and ***Complemented by lower level autonomics (GANA levels 2&3 DEs) in NEs/NFs,*** for Holistic Multi-Domain State Correlation and resources programming by the **GANA KPs** for ***Access***, ***Backhaul***, and ***Core Networks.*** Service Providers seek to deploy ***Framework for E2E Autonomic (Closed-Loop) Service Assurance for Network Services.***

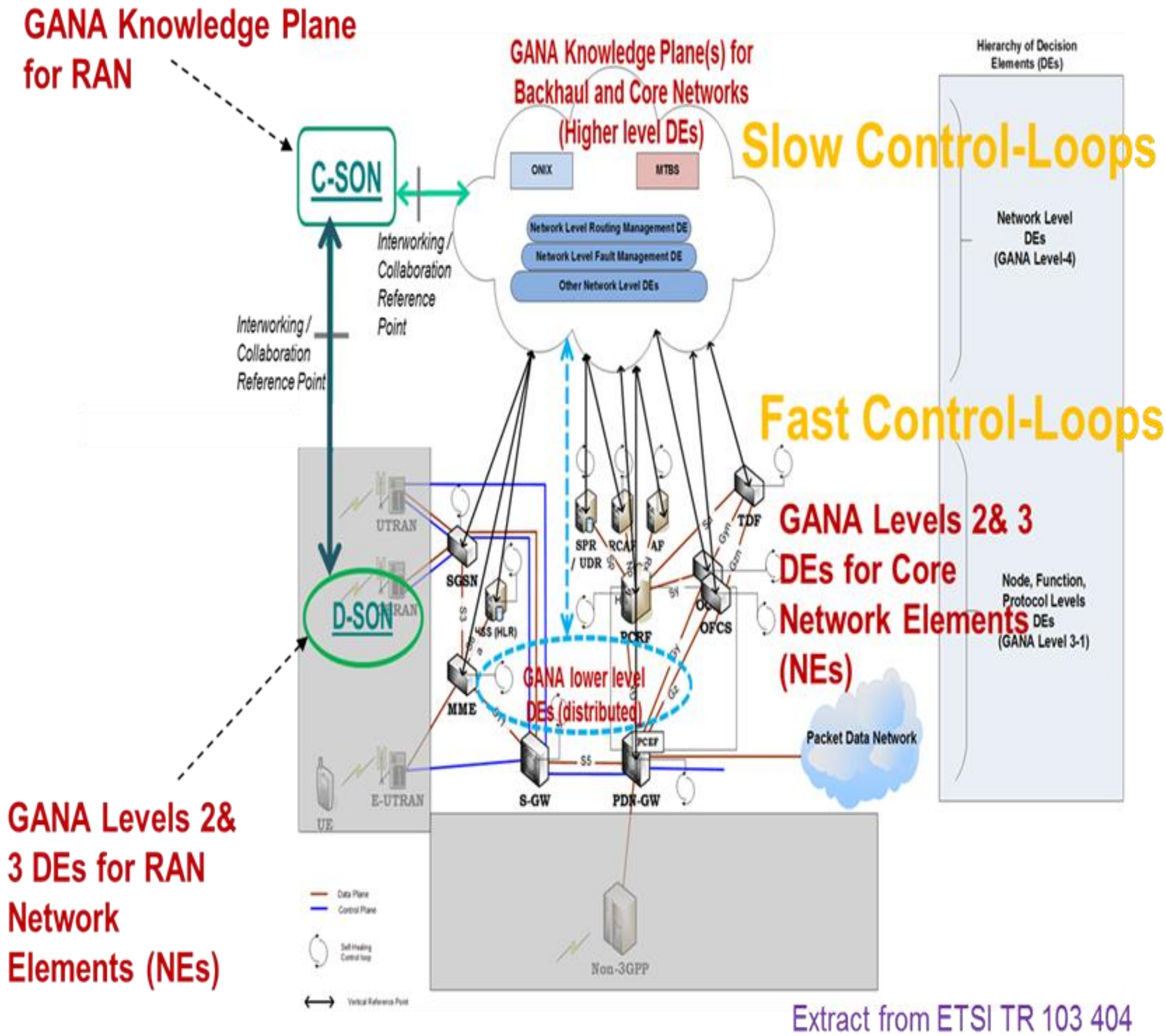


Figure 22: Federated/Interworking GANA Knowledge Planes for RAN-, Backhaul- and 3GPP Core Networks complemented by low level autonomics

Figure 22 illustrates such a framework based on ETSI TR 103 404, which discusses the subject of the need for federation of GANA Knowledge Planes for specific network segments to achieve end-to-end autonomic service assurance.

In the ETSI 5G PoC discussed in this paper, a 5G network slice in the core network can be instantiated as a virtual EPC (Evolved Packet Core) in what is referred to as the Non-Standalone Architecture (NSA) Core Network mode that is being deployed along the transition path to 5G SBA (Service Based Architecture) based core network or Standalone Architecture (SA).
For a Service Based Architecture (SBA) 5G core network, the aspect of Federation of GANA Knowledge Planes for the various network segments as part of the outcome in the ETSI 5G PoC is illustrated below, on the figure 23.
As Distributed SON (D-SON) is an implementation of GANA Levels 2 and 3 Autonomics in eNodeBs, similar NE (Network Element) level autonomics is required in NEs of the other network infrastructure segments such as Backhaul and Core Network segments. NE-local (Node-Internal) and Distributed DE Algorithms for GANA Levels 2&3 Autonomics in the Core Network elements/functions.
Examples of *Requirements* for NE level autonomics (GANA Levels 2&3) that can be implemented in the Core Network NEs and policy-controlled by KP DEs as described in ETSI TS 103195-2 [2], are as follows (refer to ETSI TR 103 404 for more details):

- NE Auto-Configuration
- MME (Mobility Management Entity) Pooling
- Energy Saving
- Signalling Optimization
- Latency Optimization
- Fast Gateway Convergence with Bidirectional Forward Detection
- Dynamic IP Pooling

The Demo-2 of the PoC focused on C-SON Evolution for 5G, Hybrid SON Mappings to the ETSI GANA Model, and Federation of GANA Knowledge Planes for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices through a Real Implementation achieved by a partner of the ETSI 5G PoC PoC Consortium. As such, ETSI 5G PoC Demo-2 covered the Autonomic (Closed-Loop) Service Assurance Use Case for 5G Network Slice(s)—with focus on the RAN part in the Framework for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices achieved in ETSI 5G PoC Demo-2. The Demo-2 presented and discussed the following (a Report can be downloaded from [3]):

- The GANA model as enabler for Vendors to Implement Components required by Telecom Operators in implementing a Framework for E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices and the Roadmap to achieving that goal.
- The value in the following ETSI documents: ETSI GANA Model (ETSI TS 103195-2 [2]); GANA Instantiation onto the 3GPP Backhaul and Core Network Architectures (ETSI TR 103 404); and GANA Instantiation onto the BroadBand Forum (BBF) Architecture Scenarios (ETSI TR 103 473).
- How Cellwize C-SON and its framework for policy control of D-SON implements the GANA Knowledge Plane for the RAN (see Figure 10 and Figure 11)
- Cellwize provides an implementation of the GANA Knowledge Plane for the Backhaul of some degree and this software has been implemented as an integral part of Cellwize C-SON
- Demo of Cellwize C-SON GUI and its Provisioning GW as an Implementation case for the ETSI GANA MBTS (Model-Based Translation Service) Functional Component.
- How GANA for the RAN is realized by Hybrid SON (C-SON (cognitive) complemented by D-SON in eNBs)
- How Cellwize C-SON and its framework for policy control of D-SON implements the GANA Knowledge Plane for the RAN
- Cellwize implementation of the GANA Knowledge Plane for the Backhaul of some degree and how this software has been implemented as an integral part of Cellwize C-SON
- C-SON Evolution for 5G
- Connected Cars Use Case and associated requirements on C-SON.

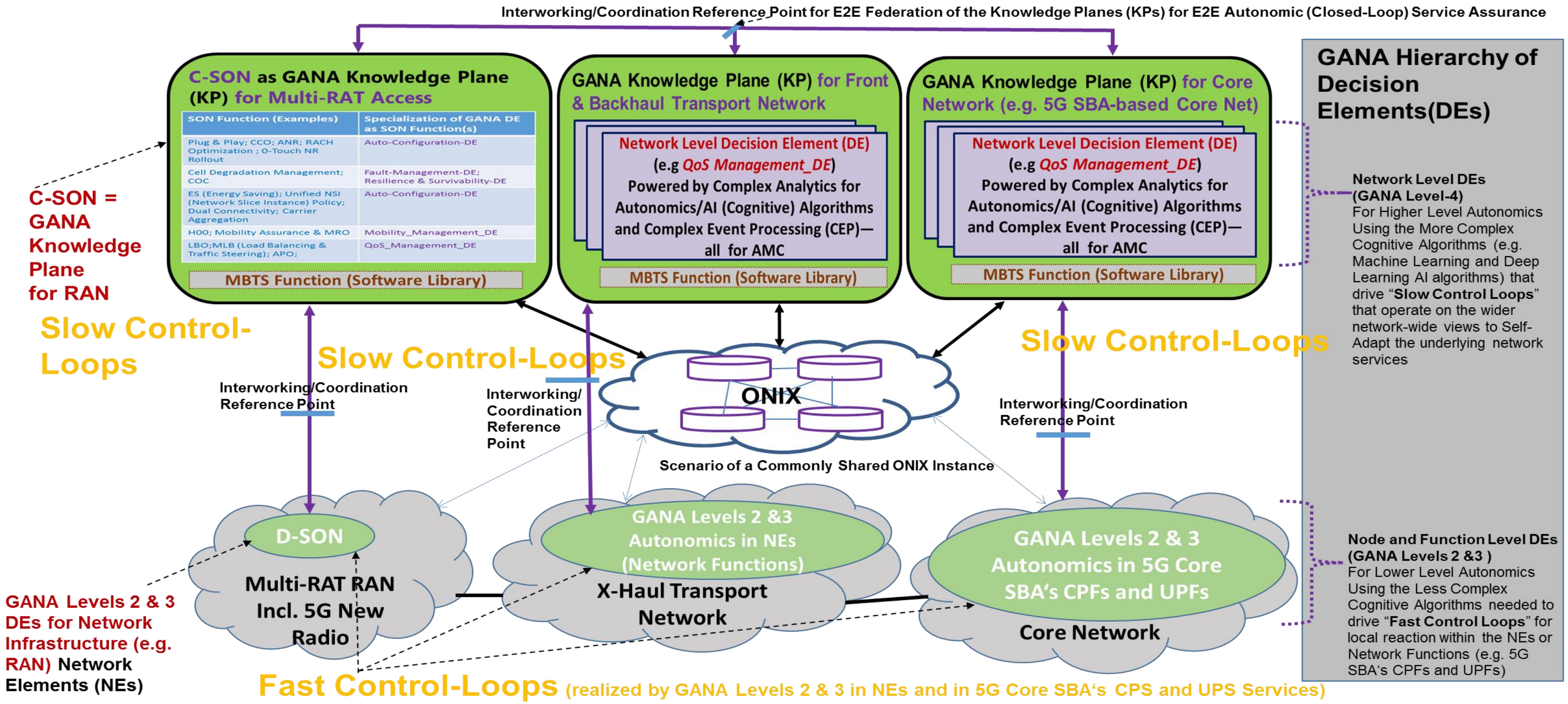


Figure 23: Framework for E2E Autonomic(Closed-Loop) Service Assurance of Network Services through the Federation of GANA Knowledge Planes (KPs) for various segments: RAN (C-SON), Front-/Backhaul, Core Network, etc., and complemented by lower level autonomics in Network Elements (NEs) or Network Functions(NFs)

14. Conclusions

The Demo-1 and Demo-2 the ETSI 5G PoC produced a Report that describes the results and discussions outcome of the Demos in terms of the Objectives described in this White Paper and the Network Operator's Requirements listed in the Problem Statement section of this White Paper. Therefore, readers are encouraged to follow the developments, progression and the results (Demo Reports (e.g. Demo-2 Report) and more detailed material in form of Slides) of the ETSI 5G PoC that are accessible at https://ntechwiki.etsi.org/index.php?title=Accepted_PoC_proposals [3], and there are plans for more demos as part of Demo series planned for the overall PoC in the timeframe 2018/2019 and beyond).

15. Summary of Further Plans on Demo series planned for the overall 5G PoC in the timeframe 2018/2019 and beyond

The ETSI 5G PoC project is initially planned to continue running in 2018-2019 timeframe but with possibility to continue beyond 2019 as guided by the various aspects of the 5G ecosystem that telecom operators would like to see addressed by standards and solution suppliers. The ETSI 5G PoC project has in plan a series of Demos beyond the Demo-2 reported in this paper, and the planned Demo series cover the topics outlined below (readers are encouraged to keep following the project and its Reports to continue to be published and updated at [3]):

- **APIs that must be exposed by RAN Virtualization Platforms to GANA Knowledge Plane for RAN (namely C-SON)** such that Slice Specific Metrics/KPIs can be exposed/communicated to the Knowledge Plane to feed into its Closed-Loop (Autonomic) Service Assurance operations for the Slices. The APIs should also enable the RAN Knowledge Plane (C-SON) to dynamically adapt (Self-Optimize) individual Slice instances according to the Slice Consumer (change Management process) or to trigger creation of new slice instances as part of service remediation and self-healing strategies. How the APIs should be an integral part of the MBTS (***Model-Based-Translation Service as a mediation service between Knowledge Plane and NEs***) for RAN is also expected to be addressed.

- **Autonomics/Self-Management (Autonomic FCAPS) through Centralized DE Algorithms in the GANA Knowledge Plane** for a particular Network Segment
  - *GANA Knowledge Plane for an Autonomic 5G Backhaul*
  - *GANA Knowledge Plane for an Autonomic 5G Fixed Access Network*
  - *GANA Knowledge Plane for an Autonomic 5G Fixed & Wireless Access (FWA) Network*
  - *GANA Knowledge Plane for an Autonomic 5G Core Network*

- **The continuing work on Federation of GANA Knowledge Planes for E2E Autonomic (Closed-Loop) Service Assurance** across Network Segments and Domains: Federation of GANA Knowledge Planes for Backhaul, GANA Knowledge Plane for the Core Network, and GANA Knowledge Plane for RAN (C-SON)

- **OSS Interface with the GANA Knowledge Plane within the transition phase to full-fledged Knowledge Planes driven management and control into the future,** though coexistence of Knowledge Planes and OSS may continue for quite some time as the two can be integrated as illustrated by the Joint SDO/Fora Unified/Integration Architecture.

- **Dynamic Probing for Orchestrated Assurance** and Enabling **Integration/Convergence of Autonomic Service Assurance with Orchestrated Assurance** (which include Test System and Probing roles for SLA violations detections and the triggering of re-orchestration or programming of network resources).
- **GANA ONIX System (*Overlay Network for Information eXchange for publish/subscribe services for Information, as sort of a Real-Time Inventory)* of Federated Information Servers** and the Scaling of a Single ONIX System to be shared by Knowledge Plane for RAN, Knowledge Plane for Backhaul and Knowledge Plane for Core Network

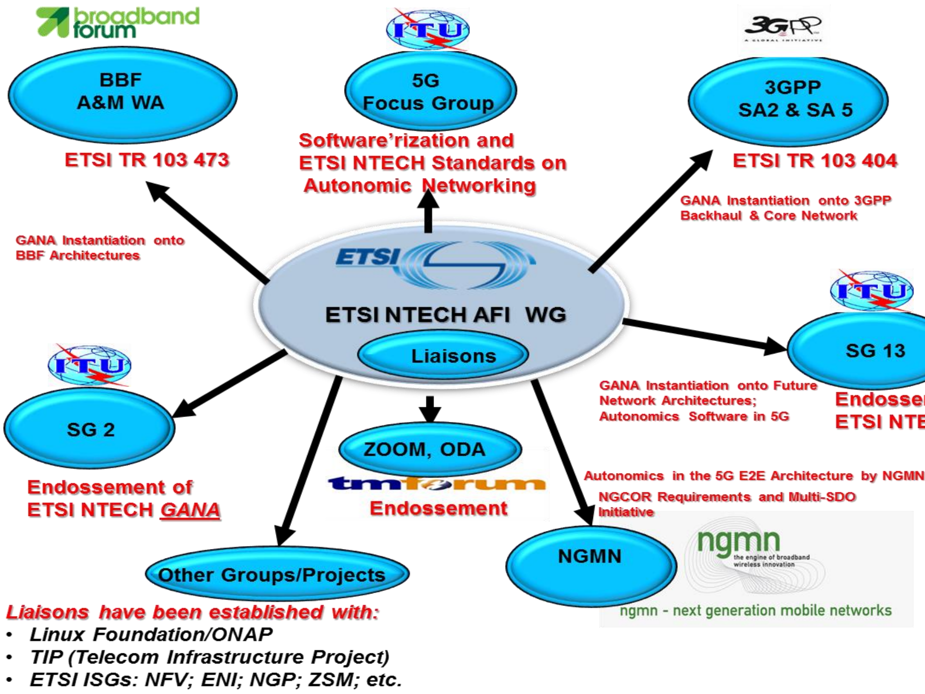
- **MBTS for RAN**; **MBTS for Backhaul**; and **MBTS for Core Network**

- **Artificial Intelligence (AI) in DE (Decision Element) Autonomics Algorithms**, for DEs at specific GANA Levels of Abstraction of Autonomics/Self-Management (with focus on the most significant **GANA Levels 2, 3 and 4,** i.e. the levels can easily be implemented as overlay software on top of existing protocols stacks without changing anything in the protocols)

- **Programmable Traffic Monitoring Fabrics that enable On-Demand Monitoring and Feeding of Knowledge into the GANA Knowledge Planes** for E2E Autonomic Service Assurance of 5G Network Slices.

16. On ETSI TC INT AFI WG and its Liaisons with other SDOs/Fora on GANA Autonomics in various Architecture Scenarios

ETSI TC INT AFI WG (previously called TC NTECH AFI WG) has established liaisons with various SDOs/Fora on the introduction of GANA autonomics in various network architectures and associated management & control architectures, and with Open Source Projects as well, as shown on the picture below. ETSI TC INT AFI WG seeks to continue to establish liaisons with various groups and projects working on emerging and future network technologies.



17. References

[1] ETSI White Paper no. 16: The *Generic Autonomic Networking Architecture Reference Model for Autonomic Networking, Cognitive Networking and Self-Management of Networks and Services*: http://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp16_gana_Ed1_20161011.pdf

[2] ETSI TS 103 195-2 (published by ETSI in May 2018): Autonomic network engineering for the self-managing Future Internet (AFI); Generic Autonomic Network Architecture; **Part 2: *An Architectural Reference Model for Autonomic Networking, Cognitive Networking and Self-Management***: https://portal.etsi.org/webapp/WorkProgram/Report_WorkItem.asp?WKI_ID=50970

[3] ETSI 5G PoC on 5G Network Slices Creation, Autonomic & Cognitive Management & E2E Orchestration—with Closed-Loop (Autonomic) Service Assurance for the IoT (Smart Insurance) Use Case: https://ntechwiki.etsi.org/index.php?title=Accepted_PoC_proposals

[4] Ranganai Chaparadza, Tayeb Ben Meriem, Dominik Spitz, David Ronen, Benoit Radier, Said Soulhi, Kostas Tsagkaris: ETSI 5G PoC on E2E Autonomic (Closed-Loop) Service Assurance of Network Slices through Cross-Domain Federation of GANA Knowledge Planes (KPs): submitted to the IEEE Magazine on Networking Standards 2018: https://www.comsoc.org/comstandardsmag/cfp/networking-standards

[5] QualyCloud Solutions: http://www.qualytrust.com

[6] Cellwize SON Solutions: http://cellwize.com/

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World Class Standards

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- **QualyCloud**
- **IPv6 Forum**

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