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TECHNICAL REPORT

Core Network and Interoperability Testing (INT/WG AFI)
Autonomicity and Self-Management in IMS architecture

Reference

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Core Network and Interoperability Testing (INT).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Executive summary

The purpose of the present document is to provide a Framework that serves to guide innovators and implementers of autonomics algorithms (including Artificial Intelligence algorithms) for what are called Autonomic Functions (AFs) instantiated into the IMS architecture and its associated management and control architecture in implementing the prescribed DEs and other GANA enablers for autonomics in IMS. The Autonomics Functions are software components called ETSI GANA Decision-making Elements (DEs) defined in the ETSI standard ETSI TS 103 195-2 [i.5].

Such prescribed GANA autonomics in IMS is meant to enable IMS functions to self-manage and at the same time be dynamically and adaptively policy-controlled by upper Artificial Intelligence-Driven Platform called GANA Knowledge Plane Platform - thanks to the introduction of Decision-making Elements (DEs) and associated control loops at the Network, Node and Function-level of the GANA reference model into the IMS network architecture and associated management and control architecture.

The Framework brings various benefits to stakeholders as described in the present document, stakeholders such as the following:

- Innovators for IMS autonomics DE algorithms, Autonomics Software Suppliers, and IMS Solutions Vendors/Suppliers.
- Communications Service Providers (CSPs) or Network Operators that deploy IMS.
- Researchers researching Autonomic Algorithms for Autonomic Service Management & Control for IMS.

Introduction

This clause introduces the Value of Autonomics in IMS in Evolving & Future Networks is described, as industry moves to Knowledge Planes (KPs) Driven Networking Era.

The following points provide a summarized view of the value of Autonomics in IMS in Evolving & Future Networks:

1) Autonomics is about Self-configuration, Self-diagnosis, Self-protection, Self-optimization, self-awareness, and other Self-* features in the management and control operations of a component (e.g. IMS Function) and the System as a whole (e.g. IMS Platform), using Control-Loops over (re)-configurable Managed Entities (MEs) and parameters of the Component/System.

2) The ETSI GANA Framework prescribes Design and Operational Principles for Autonomic Management & Control (AMC) Software Components (called GANA Decision-making Elements (DEs) that can be instantiated and implemented in Network Elements/Functions (NEs/NFs) and/or in the Management and Control realm of the associated Network Architecture.

3) Examples of Use Cases for Autonomic Management & Control of IMS Functions using GANA Knowledge Plane (KP) Platforms (defined in the clause that follows this present one and in ETSI TS 103 195-2 [i.5] in more detail) and/or by Autonomic Functions introduced and embedded within an IMS Function:

   - IMS Network Function (NF) Auto-Configuration and Adaptive Re-Configuration in detected or predicted situations or contexts.
   - Energy Saving.
   - Signalling Optimization.
   - QoS Optimization, e.g. Latency Optimization with respect processing time at NF, E2E latency, and service delivery to Users.

4) Autonomics in IMS plays an important role in the ETSI GANA based Autonomic & Cognitive Management of 5G Slices & E2E Orchestration - GANA KP Platforms should collaborate in Slice (re)-creation and Assurance based on various Situations and KPIs computed by the KPs. Operations Support System (OSS)/Business Support Systems (BSS), Management and Network Orchestration (MANO), Software-Defined Network (SDN) Controllers, etc., may be used in Slice Creation and KPs takeover the Assurance by adaptively re-programming OSS/BSS, MANO, SDN Controllers in adapting to situations by fixing problems in Slices.

5) The value of GANA autonomics introduced at a higher-level outside of an IMS function is as follows:

   - The present document introduces IP Multimedia Application Layer GANA Knowledge Plane (KP), IMS GANA Knowledge Plane (KP), and Transport Layer GANA Knowledge Plane (KP), and each is responsible for dynamic management and control of the Functions of its corresponding layer it is responsible for by using GANA DEs and DE Algorithms (which include Artificial Intelligence (AI) Algorithms) to dynamically (re)-orchestrate or (re)-configure as driven by Human Operator inputs such as service SLAs and other kinds of configuration data and situations that require the KP to compute a plan of actions to apply to the Functions of the layer in order to enforce a change in the configuration or operation of the Functions.

- Each of the KPs may perform the following, in respect of the Functions of the Layer the KP is responsible for in a standalone manner and/or in collaboration with other KPs that provide it some data/information (e.g. KPIs) of relevance to the operations:
    - Automated service orchestration and provisioning (via Management and Control Systems such as OSS/BSS, SDN Controllers, MANO, etc.).
    - Automatic service resilience and close-loop service adaptation to various challenges detected or predicted in the network such as faults/errors/failures and/or security-threats/attacks/risks and/or performance degradations of various service impacting entities.
    - Autonomic Functions Orchestrations based on resilience and survivability scenarios.
    - End to End Service Level Agreements (E2E SLAs) fulfilment and Assurance by the collaboration of the KP Platforms.
    - Security-Driven Autonomic Service Adaptation.

NOTE 1: Node (NE/NF) level Autonomics (Low-Level Autonomics) by GANA DEs introduced to operate within an IMS Function, e.g. Self-configuration case for an IMS Function such as the HSS with associated Managed Entities (MEs) is illustrated in the present document.

NOTE 2: Higher-Level Autonomics is to be realized by higher level hierarchical GANA DEs of what are called GANA Knowledge Plane (KP) Platform(s), and the present document also provides a framework for implementing GANA KP Level autonomics in the IMS architecture.

In the present document, the **Benefits the Framework for GANA Autonomics in IMS Architectures brings to Key Stakeholders** is described.

The Framework for GANA Autonomics in IMS Architectures presented by the present document brings the following benefit to the key stakeholders indicated:

1) **Benefits to Innovators for IMS autonomics DE algorithms, Autonomics Software Suppliers, and IMS Solutions Vendors/Suppliers:**
    - ETSI Framework on GANA Instantiation onto IMS offers Innovators and Autonomics Software Suppliers guidance on how to implement GANA DEs with associated Analytics and AI Algorithms for Autonomics in IMS in Evolving and Future Networks as Industry Moves to Knowledge Planes (KPs) Driven Networking Era.
    - Federation of Knowledge Planes (KPs) Platforms is required to manage E2E services as IMS is in overlay over every IP capable networks (fixed or mobile networks) and it is always interconnected with Circuit Switched networks and Legacy mobile signalling Networks.

2) **Benefits to CSPs (Communications Service Providers) or Network Operators that deploy IMS:**
    - ETSI GANA DEs instantiated into an IMS Function make the IMS function to exhibit some self-management intelligence pertaining to self-configuration, resilience, self-protecting and self-defending from attacks/risks, self-optimizing its operations, and other self-* features that can be introduced directly into an IMS Function as discussed later in the present document.
    - From OPEX reduction for IMS operations and Innovation opportunities this intelligence implemented in individual IMS functions using DE algorithms for autonomics enables CSPs to benefit from various Business and Operational Scenarios that could be envisaged. While the complementary GANA Knowledge Plane (KP) Platform(s) in IMS environment for Higher-Level Autonomics by higher level hierarchical GANA DEs offer even more benefits when combined with the DEs implemented in IMS Functions in terms of OPEX reduction in operations of IMS and Network Automation based on AI-Driven Orchestration and dynamic adaptation of IMS Services.
    - A GANA KP Platform for IMS Layer (IMS_KP) is used for self-management and control of IMS Network functions using advanced AI Algorithms and Analytics by the KP's DEs.

- GANA DEs' Control-loops can be implemented on any IMS NF for autonomic operations such as autonomic security management (self-protection and self-defense), Self-Configuration (Auto-configuration), Autonomic QoS/QoE Management, Autonomic Fault-Management, as DEs dynamically (re)-configure their associated Managed Entities (as prescribed by the ETSI Framework presented in the present document).

3) Benefits to Researchers researching Autonomic Algorithms for Autonomic Service Management & Control for IMS:

- Researchers can now bring Research Results on Autonomics Algorithms for Dynamic IMS Services to implementing autonomic IMS products according to the ETSI Framework for implementing Autonomics in IMS presented by the present document.

NOTE 3: The various Stakeholders are encouraged to join the ongoing work in ETSI TC INT AFI WG on Autonomics in IMS, or join the Open 5G PoC Program for a Joint Demos on Autonomic IMS in 5G: ETSI *5G PoC on 5G Network Slices Creation, Autonomic & Cognitive Management & E2E Orchestration - with Closed-Loop (Autonomic) Service Assurance:* https://intwiki.etsi.org/index.php?title=Accepted_PoC_proposals.

1 Scope

The present document provides a Framework of an ***Autonomicity-enabled IP Multimedia Subsystem (IMS) Architecture***. It focuses on the standardized IP Multimedia Subsystem reference architecture.

The present document describes:

- A high level GANA Autonomicity-enabled 3GPP IMS architecture, based on the instantiation of GANA Functional Blocks (FBs) for autonomics and their Reference Points (Rfps) that serve as enablers for autonomic management and control operations in IMS architecture and its associated management and control architecture. The GANA FBs include Decision-making Elements (DEs) and other types of GANA functional entities described in the present document.
- Autonomicity-enabled IMS functions like Media Gateway Control Function (MGCF), Media Gateway Function (MGF), Application Server (AS) and end to end Network Management, thanks to the instantiation of the GANA autonomics enablers onto the IMS functions and the overall IMS architecture.
- An analysis of significant GANA Decision-making Elements (DEs) for implementing Hierarchical Control-Loops for closed-loop management and control of network resources, parameters and services, and Reference Points associated with GANA Functional Blocks (FBs) that should be considered in introducing autonomics in IMS service orchestration, management and control, based on deployment scenarios.
- How to achieve E2E Closed-Loop (Autonomic) IMS Services Assurance and Security Assurance by Federated GANA Knowledge Plane (KP) Platforms.

The present document provides the recommendations that innovators and implementers of autonomics algorithms (including Artificial Intelligence algorithms) for the GANA DEs instantiated into the IMS architecture and its associated management and control architecture should follow in implementing the prescribed DEs and other GANA enablers for autonomics in IMS. Such prescribed GANA autonomics is meant to enable IMS functions to self-manage and at the same time be dynamically and adaptively policy-controlled by upper Artificial Intelligence-Driven Platform called GANA Knowledge Plane Platform - thanks to the introduction of Decision Elements (DEs) and associated control loops at the Network, Node and Function-level of the GANA reference model into the IMS network architecture and associated management and control architecture.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TS 123 228: "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; IP Multimedia Subsystem (IMS); Stage 2 (3GPP TS 23.228)".

[i.2] ETSI TS 123 002: "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Network architecture (3GPP TS 23.002)".

[i.3] BBF TR-145: "Multi-service Broadband Network Functional Modules and Architecture; Issue :1"; Issue Date: November 2012.

[i.4] ETSI TS 103 194: "Network Technologies (NTECH); Autonomic network engineering for the self-managing Future Internet (AFI); Scenarios, Use Cases and Requirements for Autonomic/Self-Managing Future Internet".

[i.5] ETSI TS 103 195-2 (2018-05): "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".

NOTE: Available at https://portal.etsi.org/webapp/WorkProgram/Report_WorkItem.asp?WKI_ID=50970.

[i.6] BBF TR-101: "Migration to Ethernet-Based Broadband Aggregation".

NOTE: Available at http://www.broadband-forum.org/technical/download/TR-101.pdf.

[i.7] BBF TR-106: "Data Model Template for TR-069-Enabled Devices".

[i.8] BBF TR-069: "CPE WAN Management Protocol Issue:1 Amendment 5", Issue Date: November 2013 CWMP Version: 1.4.

[i.9] ETSI TR 103 473 (V1.1.2): "Evolution of management towards Autonomic Future Internet (AFI); Autonomicity and Self-Management in the Broadband Forum (BBF) Architectures".

[i.10] DSL Forum TR-058: "Multi-Service Architecture & Framework Requirements", September 2003.

NOTE: Available at http://www.broadband-forum.org/technical/download/TR-058.pdf.

[i.11] White Paper Advanced Predictive Network Analytics: "Optimize Your Network Investments & Transform Customer Experience".

[i.12] Albert Mestres et al: "Knowledge-Defined Networking" ACM SIGCOMM Computer Communication Review, Volume 47, Issue 3, July 2017.

NOTE: Available at https://arxiv.org/pdf/1606.06222.pdf.

[i.13] Ren Quinn: "KnowNet: Towards a Knowledge Plane for Enterprise Network Management"; NOMS 2016.

[i.14] ETSI White Paper No.16 GANA: "Generic Autonomic Networking Architecture Reference Model for Autonomic Networking, Cognitive Networking and Self-Management of Networks and Services".

[i.15] S. Nestić, N. Pekić and M. Tutman: "Challenges and achievements during integration of IMS platform into OSS/NMS environment", In MIPRO, 2011 IEEE™ Proceedings of the 34th International Convention, Opatija, Croatia, 23-27 May 2011.

[i.16] ETSI TC INT AFI WG 5G PoC White Paper No.3: "Programmable Traffic Monitoring Fabrics that enable On-Demand Monitoring and Feeding of Knowledge into the ETSI GANA Knowledge Plane for Autonomic Service Assurance of 5G Network Slices; and Orchestrated Service Monitoring in NFV/Clouds".

NOTE: Available at https://intwiki.etsi.org/images/ETSI_5G_PoC_White_Paper_No_3_2019_v1.19.pdf.

[i.17] ETSI TC INT AFI WG 5G PoC White Paper No.1: "C-SON Evolution for 5G, Hybrid SON Mappings to the ETSI GANA Model, and achieving E2E Autonomic (Closed-Loop) Service Assurance for 5G Network Slices by Cross-Domain Federated GANA Knowledge Planes".

NOTE: Available at https://intwiki.etsi.org/images/ETSI_GANA_in_5G_PoC_White_Paper_No_1_v1.28.pdf.

[i.18] ETSI TC INT AFI WG 5G PoC 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".

NOTE: Available at https://intwiki.etsi.org/images/ETSI_5G_PoC_White_Paper_No_2_Final_v7.3.pdf.

[i.19] Paolo De Lutiis and Dario Lombardo: "An innovative way to analyse large ISP data for IMS security and monitoring", IEEE™ 13th International Conference on Intelligence in Next Generation Networks (INGN), Bordeaux, France, 26-29 October 2009, pp. 1-6.

[i.20] ETSI GS NFV-REL 004: "Network Functions Virtualisation (NFV); Assurance; Report on Active Monitoring and Failure Detection".

NOTE: Available at https://www.etsi.org/deliver/etsi_gs/nfv-rel/001_099/004/01.01.01_60/gs_nfv-rel004v010101p.pdf.

[i.21] ETSI TS 132 454: "Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Key Performance Indicators (KPI) for the IP Multimedia Subsystem (IMS) (3GPP TS 32.454)".

[i.22] ETSI GS NFV-SEC 013: "Network Functions Virtualisation (NFV) Release 3; Security; Security Management and Monitoring specification".

[i.23] Vyshak Srivatsa Raghavendra: "Implementation and Automation of Network Monitoring in Virtualized IP Multmedia Subsystem" (MS Thesis): Technische Universität Ilmenau: Fakultät für Elektrotechnik und Informationstechnik, 2016.

[i.24] Andreas Klenk, Frank Petri, Benoit Radier, Mikael Salaun, Georg Carle: "Automated Trust Negotiation in Autonomic Environments", IWSOS 2007.

[i.25] ETSI 5G PoC Report on Specifications of Integration APIs for the ETSI GANA Knowledge Plane Platform with Other Types of Management & Control Systems, and with Info/Data/Event Sources in general.

NOTE: Available at ETSI_5G_PoC_Summary_Report_NBI_APIs_for_Integrating_the_ETSI_GANA_Knowledge_Plane_Platform_v15.3.pdf.

[i.26] ETSI TC INT AFI WG 5G PoC White Paper No.4: "ETSI GANA as Multi-Layer Artificial Intelligence (AI) Framework for Implementing AI Models for Autonomic Management & Control (AMC) of Networks and Services; and Intent-Based Networking (IBN) via GANA Knowledge Planes".

NOTE: Available at https://intwiki.etsi.org/images/ETSI_5G_PoC_White_Paper_No_4_v3.1.pdf.

[i.27] ETSI TC INT AFI WG 5G PoC White Paper No.5: "Artificial Intelligence (AI) in Test Systems, Testing AI Models and ETSI GANA Model's Cognitive Decision Elements (DEs) via a Generic Test Framework for Testing GANA Multi-Layer Autonomics & their AI Algorithms for Closed-Loop Network Automation".

NOTE: Available at https://intwiki.etsi.org/images/ETSI_5G_PoC_White_Paper_No_5.pdf.

[i.28] ETSI TC INT AFI WG 5G PoC White Paper No.6: "Generic Framework for Multi-Domain Federated ETSI GANA Knowledge Planes (KPs) for End-to-End Autonomic (Closed-Loop) Security Management & Control for 5G Slices, Networks/Services".

NOTE: Available at https://intwiki.etsi.org/images/ETSI_5G_PoC_White_Paper_No_6.pdf.

[i.29] Andreas Klenk, Michael Kleis, Benoit Radier, Sanaa Elmoumouhi, Georg Carle and Mikael Salaun: "Towards Autonomic Service Control in Next Generation Networks". In proceedings of Fourth International Conference on Autonomic and Autonomous Systems, 2008. ICAS 2008: DOI: 10.1109/ICAS.2008.22.

[i.30] 5G End-to-End Architecture Framework by NGMN Alliance: P1-Requirements and Architecture: NGMN 5G E2E Architecture Framework V3.0.8.

NOTE: Available at https://www.ngmn.org/publications/5g-end-to-end-architecture-framework-v3-0-8.html.

[i.31] ODA TM Forum's Open Digital Architecture (ODA): "IG1167 ODA Functional Architecture Vision R18.0.0" (Intelligence Management Function Block).

[i.32] ODA TM Forum's Open Digital Architecture (ODA): "IG1177 ODA Intelligence Management Implementation Guide: R18.5.0" (IG1177 Release 18.5, December 2018).

[i.33] Haiyan Zhang, Mincheng Zhao, Wendong Wang, Xiangyang Gong, Xirong Que: "A novel autonomic architecture for QoS management in wired network", GLOBECOM Workshops (GC Wkshps), 2010 IEEE: 10.1109/GLOCOMW.2010.5700376.

[i.34] G. Aristomenopoulos, T. Kastrinogiannis, Z. Li and S. Papavassiliou: "An Autonomic QoS-centric Architecture for Integrated Heterogeneous Wireless Networks", Springer Mobile Networks and Applications (MONET), vol. 16, Issue 4, pp. 490-504, 2011.

[i.35] EC-funded EFIPSANS FP7 Project Deliverable: "Advanced Network Services in Autonomic IPv6 Networking: Performance Analysis and Evaluation".

NOTE 1: Available at https://secan-lab.uni.lu/efipsans-web/images/stories/INFSO-ICT-215549_EFIPSANS_WP3_D3.2.pdf.

NOTE 2: Available at https://secan-lab.uni.lu/efipsans-web/images/stories/INFSO-ICT-215549_EFIPSANS_WP3_D3.2_Appendix_I.pdf.

[i.36] Marinos C., Argyropoulos C., Grammatikou M., Maglaris V. (2011): "An Autonomic Monitoring Framework for QoS Management in Multi-service Networks". In: Pentikousis K., Agüero R., García-Arranz M., Papavassiliou S. (eds) Mobile Networks and Management. MONAMI 2010. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 68. Springer, Berlin, Heidelberg. .

[i.37] Yuhong Li, Wei Deng, Baowen Liu, Yan Shi, Zhen Cao, Hui Deng: "Autonomicity in Distributed Mobility Management", GLOBECOM workshop MENS, Dec. 5-9, 2011, Houston, Texas, USA.

[i.38] ETSI TR 103 404: "Network Technologies (NTECH); Autonomic network engineering for the self-managing Future Internet (AFI); Autonomicity and Self-Management in the Backhaul and Core network parts of the 3GPP Architecture".

[i.39] 3GPP TR 23.700-10: "Study on enhanced IP Multimedia Subsystem (IMS) to 5GC integration Phase 2; CT WG1 aspects", Release 17.

[i.40] 3GPP TR 23.700-11: "Study on enhanced IP Multimedia Subsystem (IMS) to 5GC integration Phase 2; CT WG3 aspects", Release 17.

[i.41] 3GPP TR 23.700-12: "Study on enhanced IP Multimedia Subsystem (IMS) to 5GC integration Phase 2; CT WG4 aspects", Release 17.

[i.42] ETSI TS 123 501: "5G; System architecture for the 5G System (5GS) (3GPP TS 23.501 Release 15)".

[i.43] 3GPP TR 23.794: "Study on enhanced IP Multimedia Subsystem (IMS) to 5GC integration", Release 16.

[i.44] IP Multimedia Subsystem: "3GPP/TISPAN IMS architectural overview - HSS in IMS layer (as by standard)".

NOTE: Available at https://en.wikipedia.org/wiki/IP_Multimedia_Subsystem.

[i.45] ETSI TR 103 495: "Network Technologies (NTECH); Autonomic network engineering for the self-managing Future Internet (AFI); Autonomicity and Self-Management in Wireless Ad-hoc/Mesh Networks: Autonomicity-enabled Ad-hoc and Mesh Network Architectures".

[i.46] ETSI TR 103 626: "Autonomic network engineering for the self-managing Future Internet (AFI); An Instantiation and Implementation of the Generic Autonomic Network Architecture (GANA) Model onto Heterogeneous Wireless Access Technologies using Cognitive Algorithms".

[i.47] Recommendation ITU-T Y.3324: "Requirements and architectural framework for autonomic management and control of IMT-2020 networks".

[i.48] ETSI ES 282 001: " Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN); NGN Functional Architecture".

[i.49] ETSI TS 132 409: "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Performance Management (PM); Performance measurements; IP Multimedia Subsystem (IMS) (3GPP TS 32.409)".

[i.50] Recommendation ITU-T G.1028: "End-to-end quality of service for voice over 4G mobile networks".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI TS 103 195-2 [i.5] apply.

3.2 Symbols

For the purposes of the present document, the symbols given in ETSI TS 103 195-2 [i.5] and the following apply:

2G	Second generation of mobile technologies
3G	Third generation of mobile technologies
4G	Fourth generation of mobile technologies
5G	Fifth generation of mobile technologies
xDSL	different variations of Digital Subscriber Line

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI TS 103 195-2 [i.5] and the following apply:

3GPP	3rd Generation Partnership Project
5GC	5G Core network
AF	Autonomic Function
AFI	Autonomic network engineering for the self-managing Future Internet
AGW	Access GateWay
AI	Artificial Intelligence
AMC	Autonomic Management and Control
AN	Access Network
API	Application Protocol Interface
AS	Application Server
AS-SCC	Application Server - Service Centralization and Continuity
BBF	BroadBand Forum
BCF	Border Control Function
BGCF	Breakout Gateway Control Function
BNG	Border Network Gateway
BSS	Business Support Systems
CEP	Complex Event Processing
CN	Core Network
CPE	Customer Premises Equipment
CS	Circuit Switch
CS_KP	Circuit Switch Knowledge Plane
CSCF	Call Session Control Function
C-SON	Centralized SON
CSP	Communications Service Providers
CSS	Call Stability Score
DE	Decision-making Element
DevOps	Development and Operations
D-SON	Decentralized SON
E2E	End to End

eMBB	enhanced Mobile Broadband
EMS	Element Management System
eNB	Enhanced Node B
EPC	Evolved Packet Core
FB	Functional Block
FCAPS	Fault, Configuration, Accounting, Performance and Security
FE	Functional Entity
FM	Fault Management system
FTTH	Fiber To The Home
GANA	Generic Autonomic Network Architecture
GS	Group Specification
HSS	Home Subscriber Service
I-CSCF	Interrogating Call Session Control Function
I-CSCF	Interrogating Call Session Control Function
IEEE	Institute of Electrical and Electronics Engineers
IM	IP Multimedia
IMS	IP Multimedia Subsystem
IMS_KP	IMS Knowledge Plane
INT	core network and Interoperability Testing
IoT	Internet of Things
IP	Internet Protocol
IP-CAN	IP-Connectivity Access Networks
IPFIX	IP Flow Information eXport
IPM_KP	IP Multimedia networks Knowledge Plane
IT	Information Technology
KP	Knowledge Plane
KPI	Key Performance Indicator
LMS_KP	Legacy Mobile Signalling network Knowledge Plane
LTE	Long Term Evolution
M2M	Machine to Machine
MANO	Management and Network Orchestration
MBTS	Model Based Translation Services
ME	Managed Entity
MGCF	Media Gateway Control Function
MGF	Media Gateway Function
MGW	Media GateWay
MIB	Management Information Base
ML	Machine Learning
MMC	Man-Machine Communication
mMTC	massive Machine-Type Communications
MO	Management Object
MRFC	Multimedia Resource Control Function
MRFP	Multimedia Resources Function Processor
NAT	Network Address Translation
NE	Network Element
NF	Network Function
NFV	Network Functions Virtualisation
NFVO	Network Functions Virtualization Orchestrator
NGMN	Next Generation Mobile Networks
NMS	Network Management System
OAM	Operating and Maintenance
ODA	Open Digital Architecture
ONAP	Open Network Automation Platform

NOTE: Available at https://www.onap.org/.

ONIX	Overlay Network for Information eXchange
OOB	Out-Of-Band
OPEX	OPeration EXpenditure
OSS	Operation Support System
OTT	Over The Top
PCEF	Policy Control Enforcement Function

PCRF	Policy Control Resource Function
P-CSCF	Proxy Call Session Control Function
PDP	Packet Data Protocol
P-I-S-CSCF	Proxy- Interrogating- Serving- Call Session Control Function
PLMN	Public Land Mobile Network
PM	Performance Management system
PNF	Physical Network Function
PoC	Proof of Concept
PSTN	Public Switched Telephone Network
QoE	Quality of Experience
QoS	Quality of Services
RAN	Radio Access Network
RCA	Root Cause Analysis
RCS	Rich Communication Services
Rfp	Reference point
RTP	Real Time Transport Protocol
S-CSCF	Serving Call Session Control Function
S-CSCF	Serving Call Session Control Function
SDN	Software-Defined Network
SDO	Standards Development Organization
SEC	Security
SIP	Session Initiation Protocol
SLA	Service Level Agreement
SLF	Subscription Locator Function
SNMP	Simple Network Management Protocol
SON	Self Organizing Network
SPAN	Switch Port Analyser (also called Port Mirroring)
STUN	Simple Traversal of User Datagram Protocol (UDP) Through Network Address Translators (NATs)
TAP	Test Access Point
TAS	Telephony Application Server
TC	Technical Committee
TISPAN	Telecommunications and Internet converged Services and Protocols for Advanced Networking
TMForum	TeleManagement Forum
UA	User Agent
UE	User Equipment
URLLC	Ultra-Reliable Low Latency Communications
VIM	Virtual Infrastructure Manager
vIMS	Virtual IMS
VNF	Virtual Network Function
VoLTE	Voice over LTE
VoWiFi	Voice over WiFi™
vTAP	Virtual TAP
WAN	Wide Area Network
WG	Working Group
xDSL	Digital Subscriber Line

4 About the ETSI GANA Reference Model for Autonomic Networking, Cognitive Networking and Self-Management of Networks and Services

4.1 Overview

ETSI TS 103 195-2 [i.5] defines the concept of Autonomic Manager element or "engine" (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 (AMC) (ETSI TS 103 195-2 [i.5]) defines an Intelligent Management and Control Functional Block called GANA Knowledge Plane (KP) that is an integral part of AMC Systems that provides for the space to implement complex network analytics functions performed by interworking Modularized and specialized DEs. The GANA KP DEs run as software in the Knowledge Plane and drive self-* operations such as self-adaptation, self-optimization, self-monitoring 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 North-Bound Interfaces available at the OSS, Service Orchestrator, Domain Orchestrator, SDN controller, EMS/NMS, NFV Orchestrator, etc.

The GANA KP consists of multiple modularized DEs. In contrast to non-modularized management systems, each DE is expected to be a module (as atomic block, FB) and that it should address a very specific "management domain (scope of management aspects/problems)" such that it can run as a "micro service". Examples of autonomic manager elements (i.e. DEs) are: QoS-management-DE, Security-management-DE, Mobility-management-DE, Fault-management-DE, Resilience & Survivability-DE, Service & Application management-DE, Forwarding-management-DE, Routing-management-DE, Monitoring-management-DE, Generalized Control Plane management-DE. DE components of the GANA KP are "macro" autonomic managers (atomic and modular) that drive logically centralized network-wide with slow control loops that operate in "slower timescale" than similar control-loops introduced to run in Network Elements (NEs) and operating as "fast control-loops". Macro autonomic managers (GANA KP DEs) should be complemented by "micro" Autonomic Manager components (DEs injected into NEs) that can be introduced in the Network Elements (physical or virtualized) for driving local intelligence within individual network elements to realize "fast control-loops" in network elements. Macro autonomic managers (GANA KP DEs) policy-control the "micro" autonomic managers (GANA DEs in NEs - i.e. the so-called GANA Level-2 and Level-3 in ETSI TS 103 195-2 [i.5].

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

- **GANA Network-Level DEs: Decision-making Elements (DEs)** whose scope of input is network wide in implementing "slower control-loops" that perform policy control of lower level GANA DEs (for fast control-loops) instantiated in Network nodes/Elements (NEs). GANA Network Level DEs operate in what is called the GANA Knowledge Plane (KP) and so are an integral part of a GANA KP. A GANA KP should be implemented to run as and operate as a Platform. The GANA 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 GANA Network-Level-DEs (Knowledge Plane DEs) can designed to run as a "micro service".

- **ONIX (Overlay Network for Information eXchange)** is a distributed scalable overlay system of federated information servers). The ONIX is useful for enabling auto-discovery of information/resources of an autonomic network via "publish/subscribe/query and find" mechanisms. DEs can make use of ONIX to discover information/context and entities (e.g. other DEs) in the network to enhance their decision-making capability. The ONIX itself does not have network management and control decision logic (as DEs are the ones that exhibit decision logic for Autonomic Management & Control (AMC)).
- **MBTS (Model-Based Translation Service)** which is an intermediation layer between the GANA KP DEs and the NEs ((Network Elements) - physical or virtual)) for translating technology specific and/or vendors' specific raw data onto a common data model for use by GANA network level DEs, based on an accepted and shared information/data model. GANA 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 GANA DEs. The MBTS translates GANA KP 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 GANA 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. This means the same KP DE can autonomically manage and control NEs from different vendors and with different management and control protocols that can be employed in (re)-programming the NEs when using an MBTS.

The "GANA" reference model combines perspectives on GANA DE ("Micro-Level" autonomics (defined by the so-called GANA levels-1 to Level-3 illustrated in Figure 1)) and the interworking GANA KP DE (with "Macro-Level" autonomics (realized by the GANA Knowledge Plane)) as well as the responsible Functional Blocks and Reference Points that enable developers to implement autonomics software, with all perspectives combined together so as to capture the holistic picture of autonomic networking, cognitive networking and self-management design and operational principles. This ETSI GANA Framework is illustrated in Figure 1.

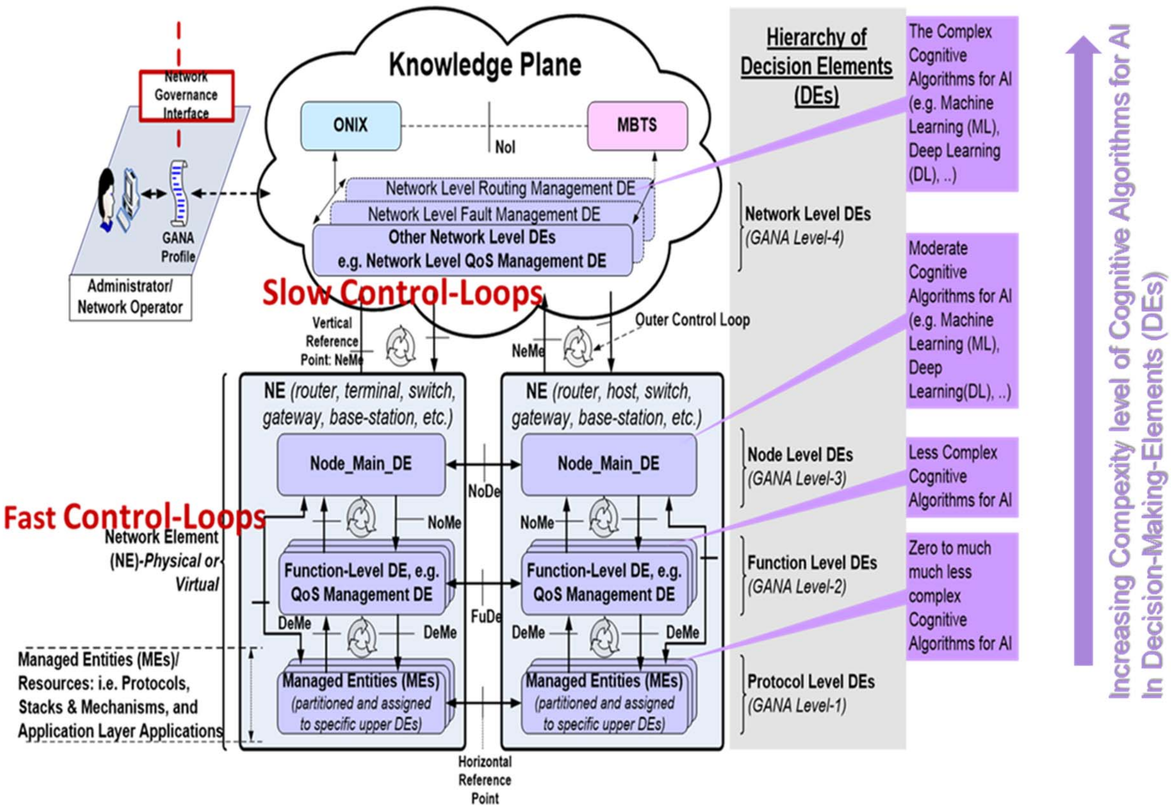

Figure 1: Snapshot of the GANA Reference Model and Autonomics Cognitive Algorithms for Artificial Intelligence (AI) and illustration of the notion of increasingly varying complexity of AI from within an NE/NF up into the Knowledge Plane level

According to the ETSI GANA Knowledge Plane (KP) concept, a Knowledge Plane (KP) Platform views various management and control systems such as SDN Controllers, OSS, Orchestrators, EMS's/NMS's and NFV MANO Components as event data sources and also as components or systems through which the Knowledge Plane can dynamically program the underlying network infrastructure (such as a policy enforcement point(s)). As illustrated on Figure 2, other data sources may be used in implementing the Knowledge Plane. Figure 2 illustrates the various kinds of APIs that may be required to integrate the ETSI GANA Knowledge Plane (KP) Platform with OSS/BSS, Orchestrators, Production Network SDN Controllers, NMS/EMS, NFV MANO, SDN Controllers for OOB (Out-Of-Band) Monitoring Fabrics, Traffic Probing & Analytics Platforms, Telemetry Data Lakes, and Big Data Analytics Apps, Ticketing Systems, and other types of Info/Data/Event Sources that should feed the target GANA KP Platform with data, information, or events. These aspects are further illustrated in White Paper No.6 of the ETSI 5G PoC project [i.28]. ETSI TS 103 195-2 [i.5] specifies APIs that should enable to integrate ETSI GANA Knowledge Plane (KP), SDN, NFV, E2E Orchestration, Big-Data driven analytics for AMC, and OSS/BSS systems (or configuration management systems in general). More details on this subject are found in [i.25], White Paper No.2 of ETSI 5G PoC project [i.18], White Paper No.3 of ETSI 5G PoC project [i.16]. White Paper No.2 of ETSI 5G PoC project [i.18] presents an approach to implementing a KP Platform using the ONAP open source software, and White Paper No.2 of ETSI 5G PoC project [i.18] also discusses how other open source products such as those listed in White Paper No.6 of ETSI 5G PoC project [i.28] can be used in implementing a KP Platform that integrates with other management and control systems depicted on Figure 2, such as SDN controllers, NFV MANO stacks, etc.

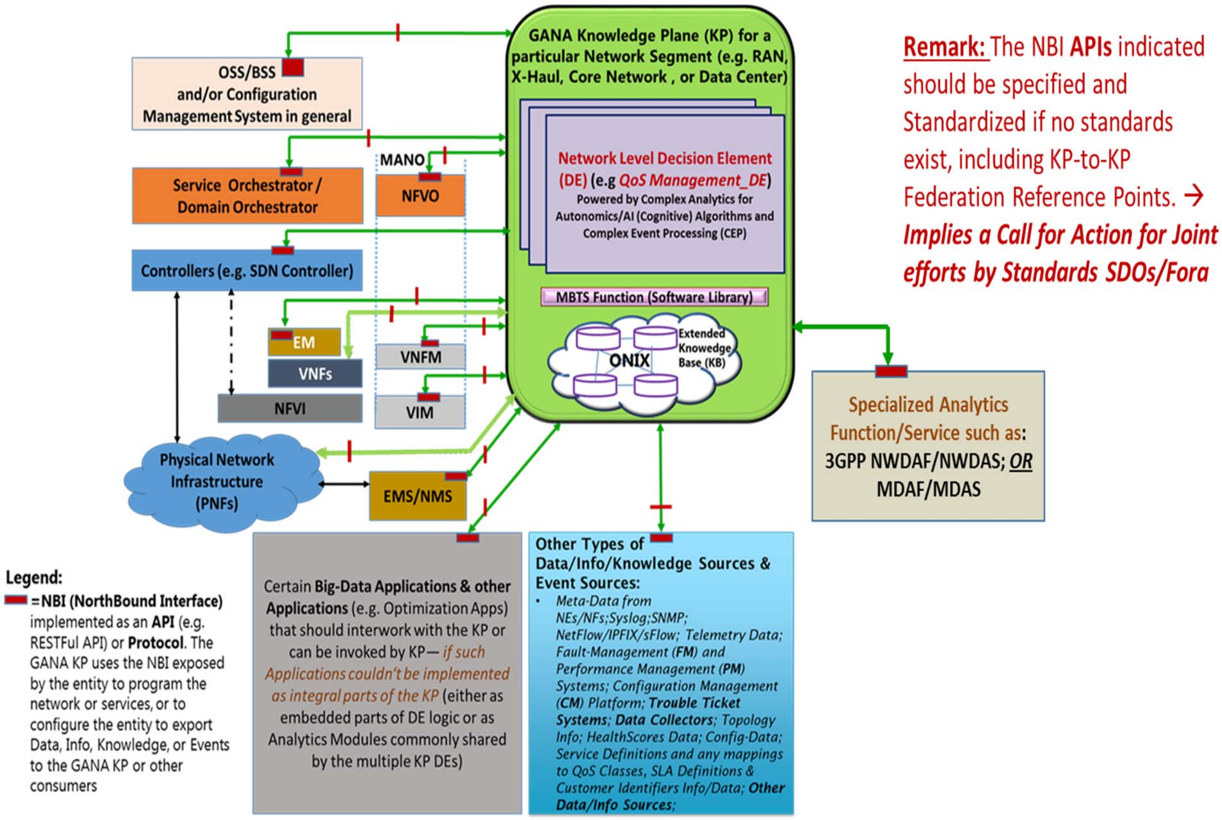

Figure 2: The Integration of the GANA Knowledge Plane (KP) with various management and control systems through which the Knowledge Plane can selectively program the network and KP integration with Event Sources, Data Sources and Info/Knowledge Sources

NOTE 1: While considering the GANA DEs implementations, GANA Levels 2 and 3 DEs instantiated to operate in specific NEs/NFs of a network and their GANA KP level "mirror DEs", from an implementation point of view there are two Scenarios or Options that can be pursued. Because GANA allows for the implementer to either implement autonomics through "centralized DE algorithms" in the GANA KP Platform Level only and/or choosing to implement some GANA DE algorithms as "distributed DE algorithms". Distributed DE algorithms are those that involve GANA levels 2 or 3 DEs communicating horizontally within the NEs/NFs of the network (for a certain scope of NEs/NFs within the network) to realize "in-network self-management and control". Telemetry protocols will remain applicable in various ways and in some cases the intelligence that lower level GANA DEs can bring about in a NE/NF can help limit or reduce the amount of telemetry data that would need to be exported directly from NEs to the external data collectors and/or to a GANA KP Platform. When GANA levels 2 and 3 DEs are implemented in NEs/NFs their local reactions intelligence help in reducing the overloading of the NEs/NFs with burden of collecting and exporting huge data to the outside world. Though, still certain meta data such as Simple Network Management Protocol (SNMP) and IP Flow Information Export (IPFIX) data of limited volume could still be exported by NEs/NFs (with or without embedded DEs)to central Data Collectors (Data Lake) that feed data or synthesized knowledge (by AI algorithms running on the Collectors) into the GANA KP Platform for consumption by GANA KP DEs, provided that such data helps build knowledge required by the GANA KP Platform for its closed-loop autonomic operations.

In general, as discussed in the ETSI documents and also bearing in mind that the GANA Model is a "generic model" meant to guide management and control intelligence innovators on how to introduce autonomics in network architectures (both, existing ones and so-called Future Network architectures like those being defined in various SDOs (e.g. ETSI, ITU, IEEE)), the way to introduce GANA autonomics in network architectures and their associated management and control architectures can take different approaches as indicated and described below and in ETSI White Paper No.16 [i.14] and ETSI TS 103 195-2 [i.5]:

1) Top down approach - whereby the first step could focus on introducing Autonomics by the GANA KP (as Umbrella Analytics Platform) and being integrated to exercise closed-loop (autonomic) operations via Management and Control systems in a particular environment without introducing yet any intelligence (GANA level 2 and 3) in NEs/NFs by lower level GANA DEs injections into NEs/NFs, and then secondly going down to introducing low level autonomics in NEs/NFs.

2) Bottom up approach - whereby low level autonomics (for "fast control-loops") is introduced into the NEs/NFs and then complemented by GANA KP level autonomics.

3) Holistic approach that considers introducing GANA KP level autonomics and lower level GANA autonomics at the same time (with KP level autonomics policy-controlling lower level GANA autonomics in NEs/NFs always) as has already happened in the case of RAN with C-SON (Centralized -SON) as KP level autonomics for RAN and Distributed SON (D-SON) as low level autonomics in eNBs with Centralized SON (C-SON) policy-controlling D-SON.

NOTE 2: Autonomics in an NE brings its own value and should be complemented by Autonomics in the Knowledge Plane level, as defined by the GANA principles. KP Level DEs policy controls the low level DEs in NEs.

There are now a number of ETSI GANA instantiations by ETSI in collaborations with other SDOs/Fora, such GANA onto BBF architectures (i.e. ETSI TR 103 473 [i.9]); GANA onto 3GPP Backhaul and Core Architectures (ETSI TR 103 404 [i.38]); GANA onto Ad-Hoc Mesh Networks (ETSI TR 103 495 [i.45]); GANA onto Heterogeneous Wireless Networks (ETSI TR 103 626 [i.46]); GANA in TMForum ODA architecture [i.31], [i.32] and GANA in NGMN 5G E2E Architecture [i.30] and ITU IMT 2020 architectures (Recommendation ITU-T Y.3324 [i.47]).

Figure 3 illustrates the need for coordination of KP DEs in achieving global autonomics/AMC objectives. More details on this subject are covered in ETSI TS 103 195-2 [i.5] and ETSI 5G PoC White Paper No.2 [i.18].The GANA Network level Auto-Configuration and Discovery DE is the main coordinator of DEs' actions that require coordination and synchronization with the other GANA KP DEs according to technical or business objectives.

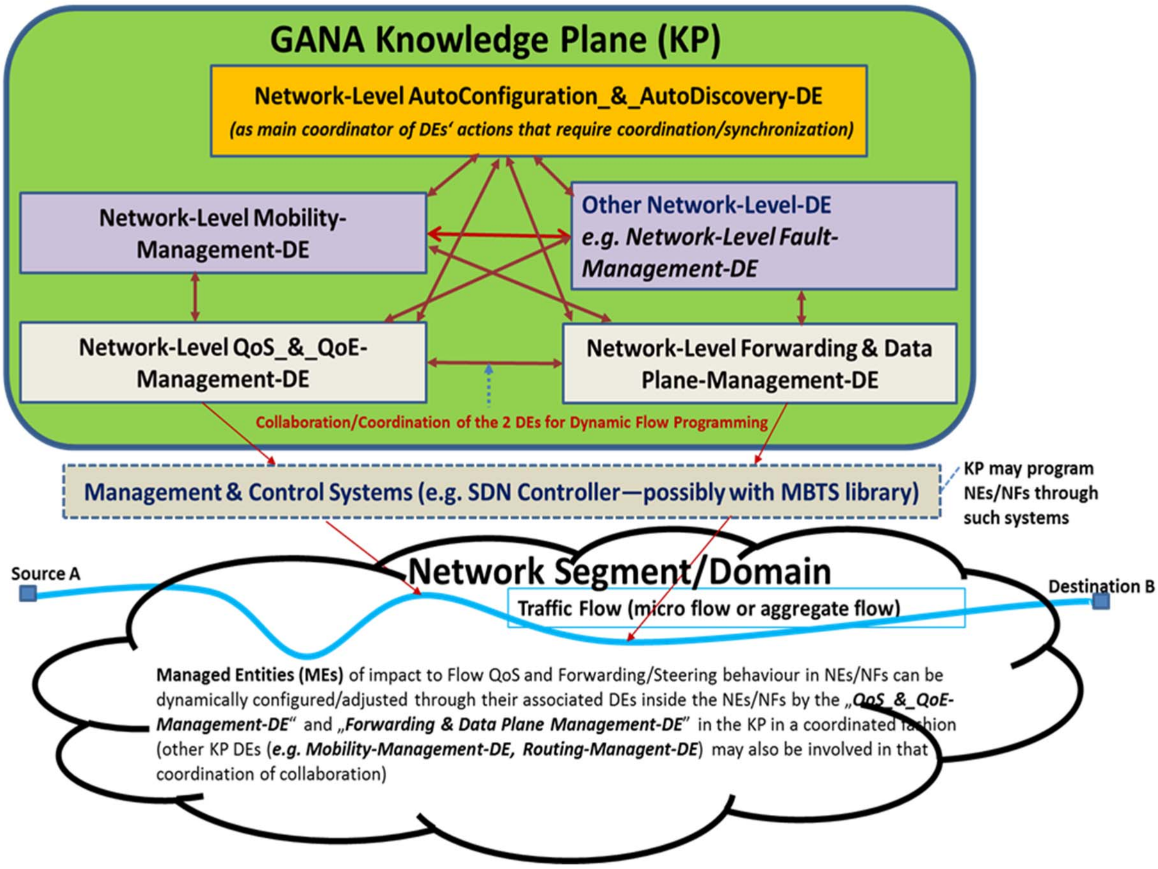

Figure 3: Need for collaboration or coordination of Autonomic Functions (DEs) on certain actions or aspects that are better addressed through collaboration/coordination

Figure 4 provides elaboration on GANA KP DEs interactions in exchanging information/knowledge that enable the coordinating GANA KP DEs to use the information in their decisions on adaptively (re)-configuring their respective Managed Entities (MEs). More details on this subject are covered in ETSI TS 103 195-2 [i.5] and ETSI 5G PoC White Paper No.2 [i.18].

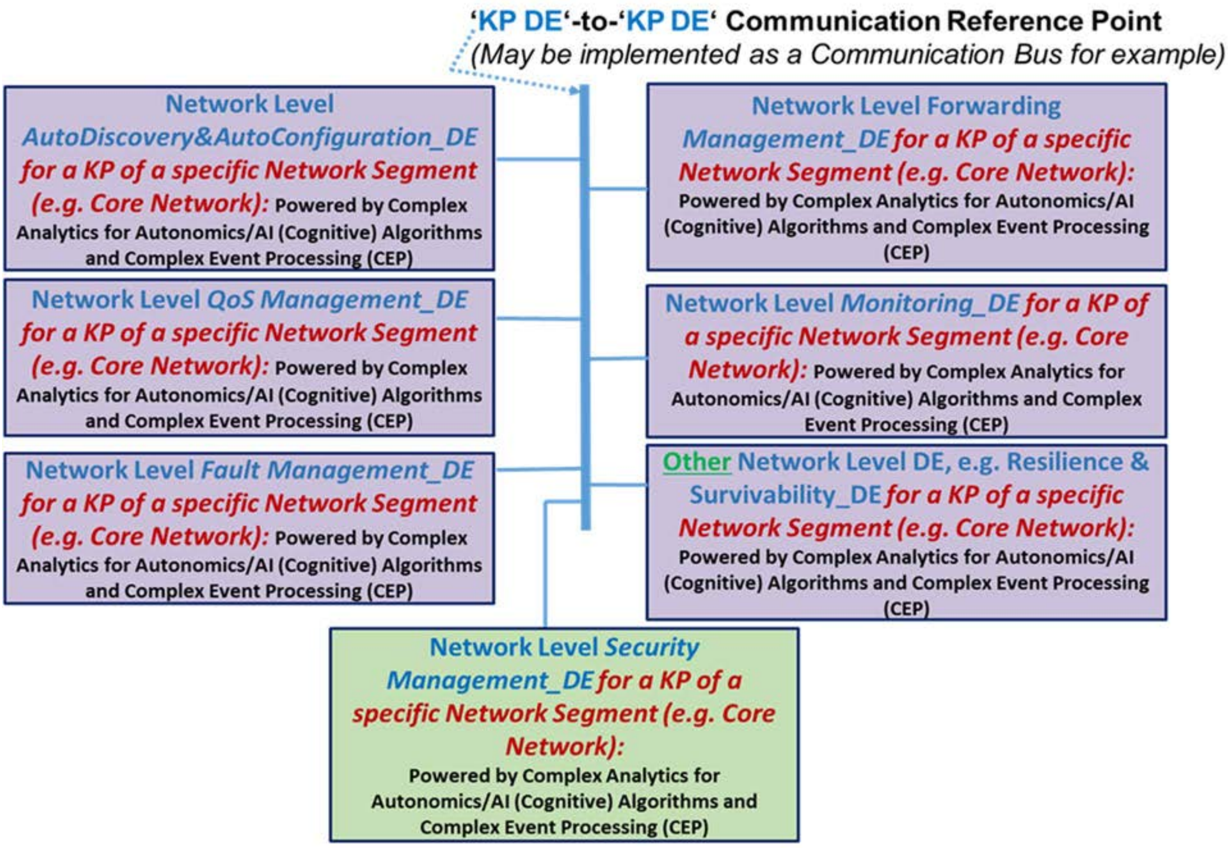

Figure 4: Elaboration on KP DEs interactions in exchanging information/knowledge that enable the coordinating KP DEs to use the information in their decisions on adaptively (re)-configuring their respective Managed Entities (MEs)

4.2 ETSI GANA Knowledge Plane (KP) Platform Positioning and Integration as a part of a Multi-Layer AI Framework for E2E Closed-Loop (Autonomic) Service & Security Assurance

This clause provides some insights on ETSI GANA KP Platform positioning and integration as a part of a Multi-Layer Artificial Intelligence (AI) Framework for E2E Closed-Loop (Autonomic) Service & Security Assurance in general. Figure 5 presents ETSI GANA KP Platform Positioning and Integration as a part of a Multi-Layer AI Framework for E2E Closed-Loop (Autonomic) Service & Security Assurance.

The insights build on the *Integration Aspects for the GANA Knowledge Plane (KP) Platform* discussed in clause 4.1 with respect to GANA KP Platform integration with various management and control systems. Such aspects are enhanced by the following additional complementary aspects:

- The Integration of the GANA KP with various management and control systems through which the GANA KP can selectively program the network.
- GANA KP integration with various Event Sources, Data Sources, and Info/Knowledge Sources.
- GANA KP driven "Open-Loop" and "Closed-Loop"(Autonomic) Service and Security Assurance for SDN Environments, with the capability of the Security Management-DE and the Monitoring- DE of the GANA KP being able to collaborate in triggering On-Demand Traffic Monitoring in the Network for Analytics (e.g. for Analytics of Suspected Traffic).

- By interacting with the SDN Controller(s) of the Production Network the Closed-Loop Analytics GANA KP Platform Executes Remediation Strategies automatically by making Certain Configuration Changes to the Network via SDN Controllers for the Production Network; and Analytics Platform continuously retrieves Health Scores, Monitoring/Telemetry Data, Topology and Configuration-Data from the SDN Controllers for the Production Network and from Network Elements/Functions (NEs/NFs).

- Through the SDN Controller (s) for the TAP & SPAN Aggregation Network as illustrated later in clauses 6.2 and 6.3 and in ETSI 5G PoC White Paper No.3 [i.16], the GANA KP DEs (particularly the Network Level Monitoring-DE) can trigger the SDN Controller to configure SPAN Sessions on-demand via SDN Controller for the Production Network to force copied traffic to flow to an Out-Of-Band (OOB) that is programmable by the SDN controller for the OOB to forward traffic to various Analytics Tools in the Centralized Analytics Tools Farm (e.g. Probes and Security Analytics Tools). ETSI TS 103 195-2 [i.5] provides insights on how the Network Level Monitoring DE of the GANA KP Platform can be implemented.

- There are other systems that can serve as Data Sources of the GANA KP Platform, e.g. PM (Performance Management system) and FM (Fault Management system) for Network and for IT (Information Technology) environments; NEs/NFs.

- The GANA KP Platform may need to send some messages to the components and systems such as the ones indicated on Figure 5 and Figure 14. For example, the GANA KP DEs such as the Network Level Security Management-DE need to integrate with Ticketing Systems in order to consume events from the Ticketing Systems. The Network Level Security Management-DE may be interested in events that may be linked to security attacks incidents and use such events to compute and apply self-defense strategies for the network. The concept of self-defense is covered in more details in clause 6 of the ETSI TC INT AFI 5G PoC White Paper No.6 [i.28]. When a problem linked to a particular security incident related Ticket has been resolved and fixed by the GANA KP as a whole, the Ticket is then cleared by the Network Level Security Management-DE as Dynamic Updates on Tickets Resolutions/Clearance by GANA KP DEs, i.e. the GANA KP DE accesses the Ticketing System to clear the Ticket if the problem has been found and fixed by the GANA KP.

- A human Service & Network Troubleshooter needs to primarily interface with GANA KP Platform (see Figure 14) for certain needs linked to Service and Network Troubleshooting in case the GANA KP is operating in an "Open-Loop" Mode and the human in the loop is required during troubleshooting scenarios. The human user may choose to interact with the components marked as "Secondary Service Troubleshooting Position".

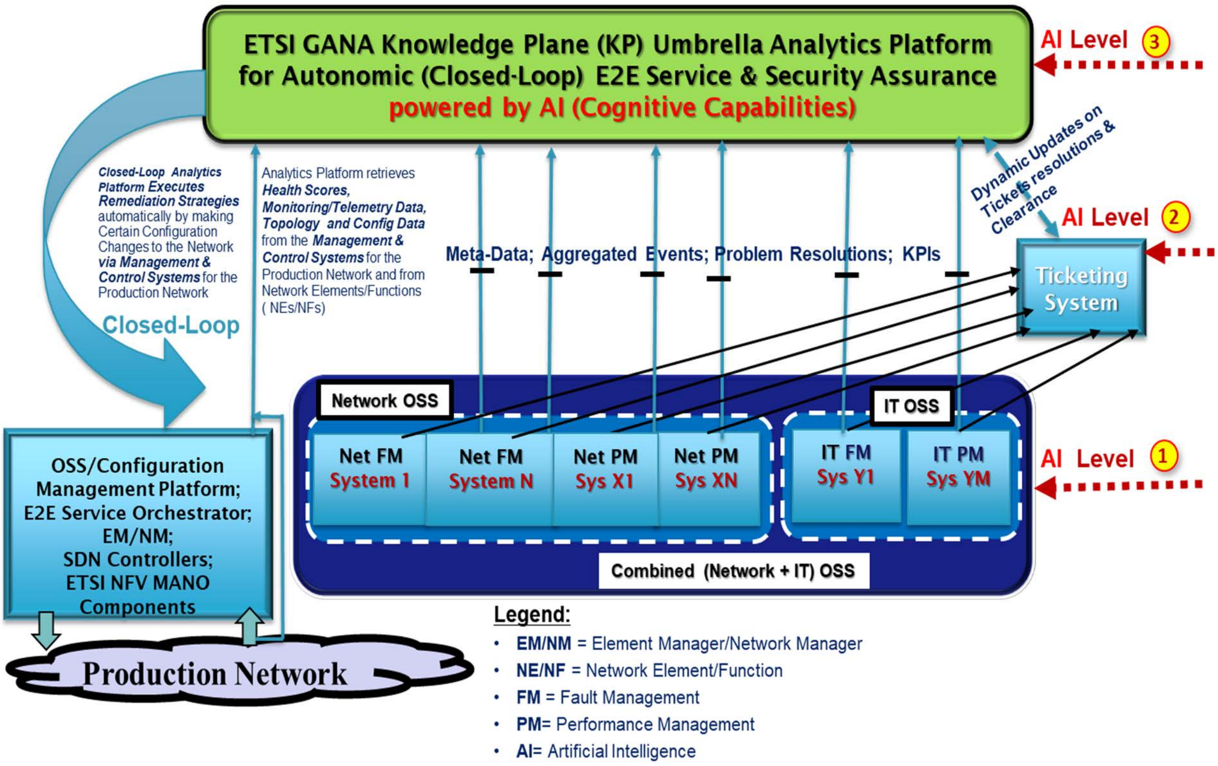

Figure 5: ETSI GANA Knowledge Plane (KP) Platform Positioning and Integration as a part of a Multi-Layer AI Framework for E2E Closed-Loop (Autonomic) Service & Security Assurance

The Aspects that should be addressed by AI at (1), (2) and (3) Levels of Multi-Layer AI (see Figure 5) are:

- Efficient, Cost Effective and Smart Data Distribution by avoiding sending "noise" event related traffic (e.g. large volumes of Alarms that are uncorrelated and are simply noises).
- Integration aspects concerning Data Flow into the GANA KP Umbrella Platform, e.g. the AI employed at the OSS Platforms level can help in determining the kinds of Meta-Data, Aggregated Events, Problem Resolutions, and KPIs that can be produced by the OSS Platforms and shared or forwarded from other sources that may have supplied them to the OSS layer.
- Closed-Loop Automation aspects: Remediation Strategies and Templates execution, and the Programmability of Network Infrastructure through Management & Control Systems (SDN Controllers, MANO, Orchestrators, EMS/NMS, OSS).
- GANA KPs are differentiated by Al Algorithms and Data Feeds Coverage Requirements.

5 IMS Reference Scenario considered for the Introduction of GANA Autonomics in IMS

5.1 Working IMS Reference Architecture

The IP Multimedia Core Network (CN) subsystem comprises all Core Networks elements for provision of multimedia services. This includes the collection of signalling and bearer related network elements as defined in ETSI TS 123 002 [i.2]. IP multimedia services are based on an IETF defined session control capability which, along with multimedia bearers, utilizes the IP-Connectivity Access Network (this may include an equivalent set of services to the relevant subset of Circuit Switched (CS) Services).

In order to achieve access independence and to maintain a smooth interoperation with wireline and wireless terminals across the Internet, the IP multimedia subsystem attempts to be conformant to IETF "Internet standards". Therefore, the interfaces specified conform as far as possible to IETF "Internet standards" for the cases where an IETF protocol has been selected, e.g. SIP.

The IP Multimedia Core Network (IM CN) Subsystem (IMS) enables telco operators to offer their subscribers multimedia services based on and built upon Internet applications, services and protocols. There is no intention here to standardize such services within the IM CN subsystem, the intention is that such services will be developed by telco operators and other third party suppliers including those in the Internet space using the mechanisms provided by the Internet and the IM CN subsystem. The IM CN subsystem should enable the convergence of, and access to, voice, video, messaging, data and web-based technologies for the wireless and wireline user and combine the growth of the Internet with the growth in telecommunications.

The complete mobile solution for the support of IP multimedia applications consists of SIP user agents in terminals, IP-Connectivity Access Networks (IP-CAN), and the specific functional elements of the IM CN subsystem are described in ETSI TS 123 228 [i.1] which has been produced by ETSI 3rd Generation Partnership Project (3GPP). An example of IP-Connectivity Access Network is the mobile or fixed networks.

The complete wireline solution for the support of IMS in fixed network and the specific functional elements of the IM CN subsystems are described for the home gateway Customer Premises Equipment (CPE) WAN management in BBF TR-069 [i.8], the fixed multimedia user agent data model BBF TR-106 [i.7] and Reference BBF architecture in BBF TR-101 extended in BBF TR-145 [i.3].

The autonomic fixed broadband network is described in "**Autonomic network engineering for the self-managing Future Internet (AFI);** Autonomicity and Self-Management in the Broadband Forum (BBF) Architectures" (ETSI TR 103 473 [i.9]). BBF TR-101 [i.6], "Migration to Ethernet Based Broadband Aggregation" defined the fixed network architecture used worldwide by most service providers deploying xDSL or fibber access. TR-101 places technical requirements onto network nodes for supporting the service and business requirements described in TR-058 [i.10]. Interconnection with fixed access and NAT traversal function are described in annex A of ETSI TS 123 002 [i.2].

Figure 6 below represents the IMS reference architecture including interfaces towards legacy networks and other IP based multimedia systems. Details of the roles of these nodes are described in [i.19].

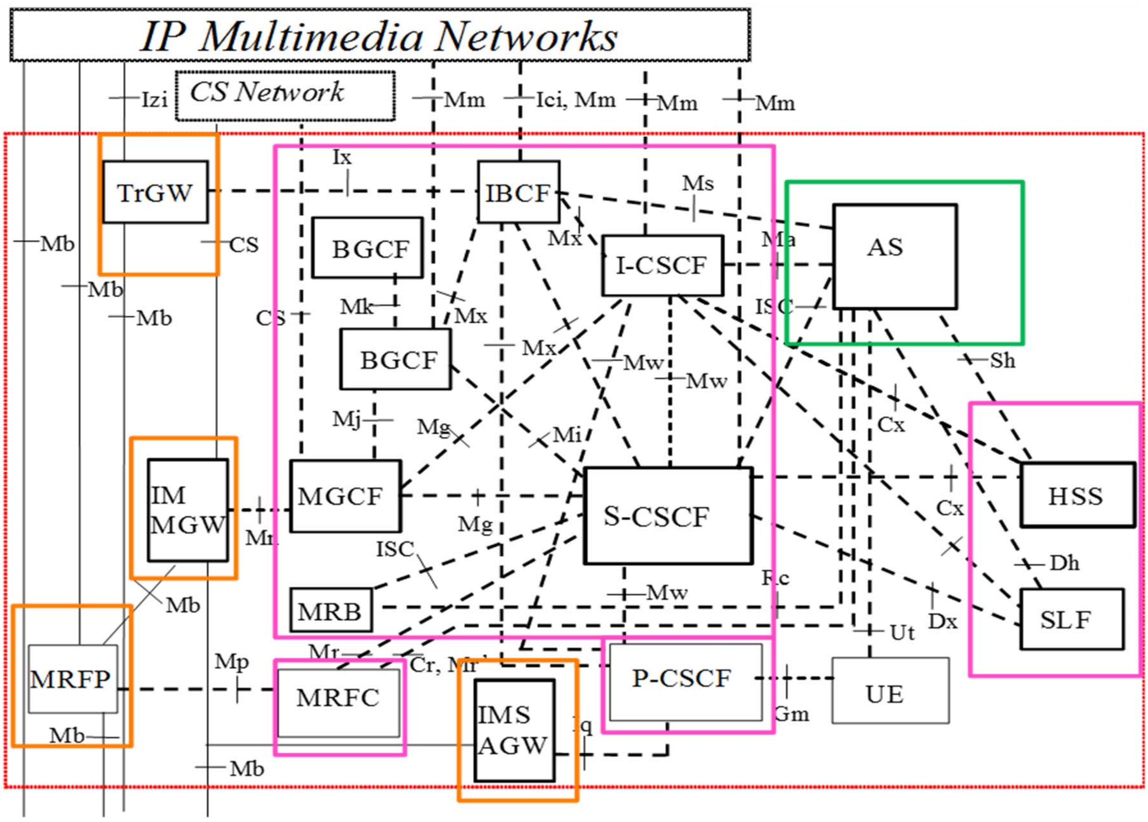

Figure 6: ETSI TS 123 228 [i.1] Reference Architecture of the IP Multimedia Core Network Subsystem

It should be noticed that the IMS was selected by the broadband forum for provision of IP multimedia services. The description of the IMS subsystem functional entities is defined in ETSI TS 123 228 [i.1], annex N (normative): Aspects for use of Common IMS in Fixed xDSL, Fibber and Ethernet based systems.

IMS is an overlay over every IP capable networks IP-Connectivity Access Networks (IP-CAN). The description below presents the different plane of the IMS.

The orange boxes are the transport IP media functions within the User plane (RTP). The orange boxes may be very specific according to the access used by the UE for example within VoLTE the IMS AGW manage specific codec and compressed IP transport layer (Packet Data Protocol (PDP) session).

The Pink Boxes are the control plane functions within the IMS Control plane (SIP). The Proxy Interrogating Server Call Session Control Functions (P-I-S CSCF) and the HSS are the main Functions of the control plane. The other functions are used for interworking issues and the MRFC is used to control the multimedia streaming server (e.g. voice call messaging server).

The green box is the IP Multimedia Application Server within the Service/Application plane. The main AS are:

- Telephony Application Server (TAS) manage telephony services.
- Application Server - Service Centralization and Continuity (AS-SCC) manage application SIP mobility for VoLTE services it is used as the anchor point of SIP signalling sessions. SIP mobility is used to manage mobility of multimedia session in overlay of IP-CAN.
- AS could be developed by third party, and could also provide video services.

5.2 IMS Services and Network Environments Integration

IP multimedia subsystem network is designed to provide a convergence multimedia services access for any multimedia user equipment (UE) connected on fixed and mobile network IP-CAN. IMS is designed to facilitate the integration of new Applications Services (AS) even from Over the Top (OTT) players and interconnect with legacy Circuit Switched (CS) network (fixed and mobile), Legacy mobile signalling Network as it is depicted in Figure 7 below.

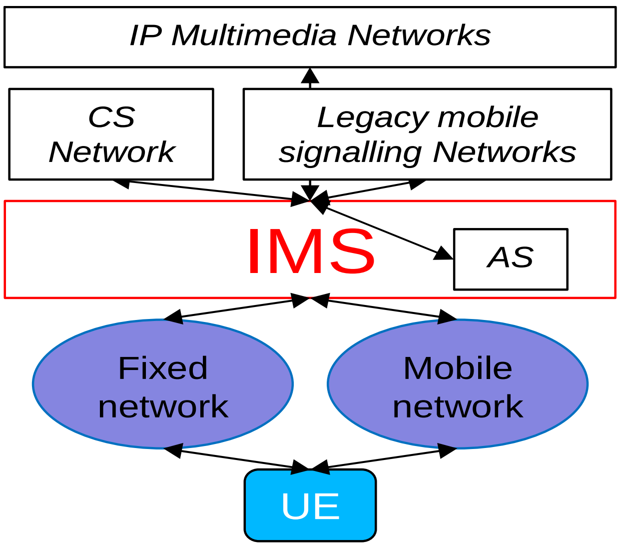

Figure 7: IP multimedia network environment

IMS services delivered multimedia services to UE over IP control with Session Initiation Protocol (SIP) from SIP user agent within the UE up to Application Services (AS). As IMS is interconnected with different players which could impact with their own network domains (e.g. mobile and fixed access network) the management of the IMS need an interconnection with the different management network used to deliver IMS services which have SLA with IMS network (e.g. access network, core network, circuit switch and packet data network; fixed and mobile networks, roaming, Circuit Switched Networks).

Figure 8 below depicts the different IP multimedia flows between the different networks domains and players interconnected.

Even if roaming reference point have been specified, the Circuit Switched Networks is mainly used for interconnection between telco providers. As IMS roaming interconnections required that all providers have launched an IMS which is not the case.

Even if the IMS control plane within the fixed and the mobile networks have the same specification, there are some specificities in the products which require different platform for the fixed and the mobile network. The specificities were developed because in some case regulatory authorities do not authorize a common subscriber platform between fixed and mobile user, or in other case within the provider organizations there are different entities with no link which work for the fixed or the mobile network. Standardization started to work on interoperability between fixed and mobile IMS as providers announced the end of Circuit Switched network (However some services will still require circuit switched network for some years (e.g. Roaming and some services not available in IMS)).

As all the services of the Circuit Switched (CS) network have not been developed within IMS, the CS Networks or Public Land Mobile Network (PLMN) are mainly used to manage legacy CS services. It is why Interoperability between mobile IMS and Fixed IMS is done by the PLMN. Mobile voice continuity is managed by the PLMN if the call is not between VoLTE UE or VoWiFi. Interoperability between Fixed IMS and Public Switched Telephone Network (PSTN) is done by the PSTN as is depicted in Figure 8.

The main interoperability's functions between network domains are the Media GateWay (MGW) and Media Gateway Control Function (MGCF). For example, within the fixed network these functions as to manage STUN server to open an RTP NAT session within the CPE. Within the mobile network the MGW/MGCF as to manage the compressed header (aggregated payload RTP/RTCP/UDP/IP) encapsulated in PDP session.

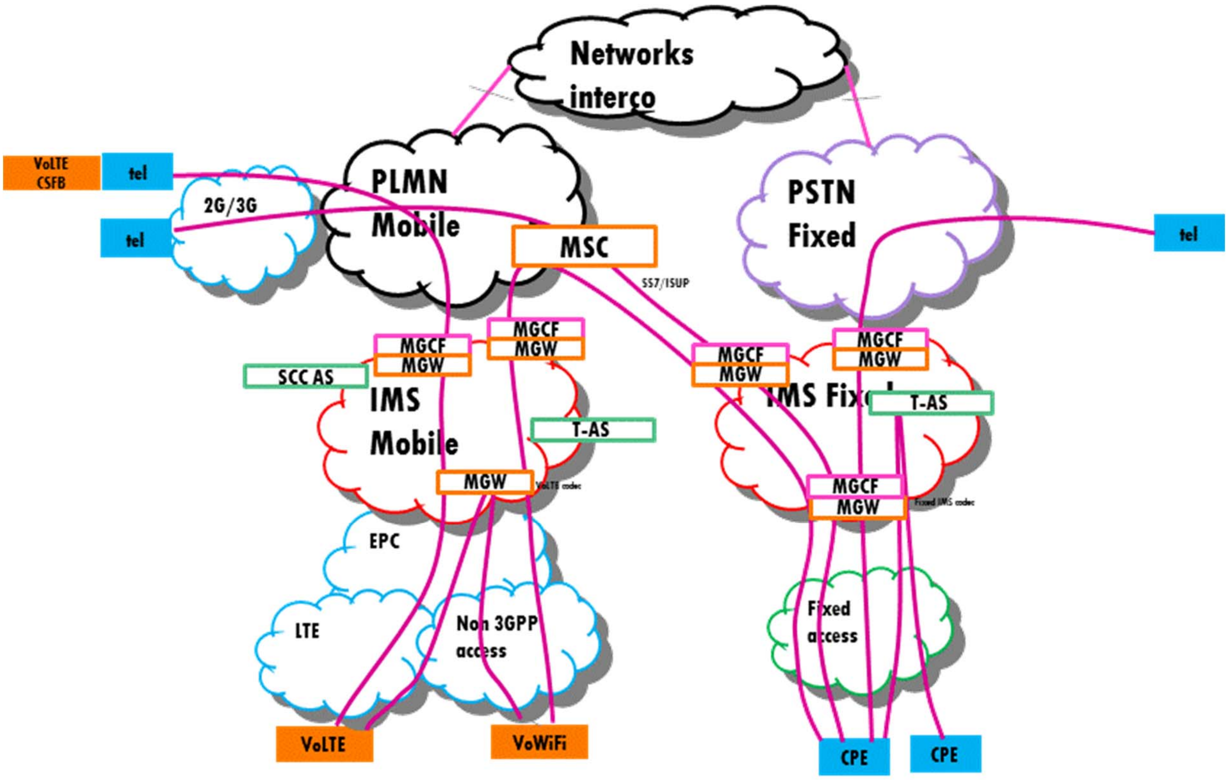

Figure 8: Multimedia session flows

5.3 Use Cases for Autonomic Management and Control (AMC) in IMS architecture and its associated Management and Control Architecture

There are various use cases for autonomics in IMS architecture and its associated management and control architecture. Some of the use cases relate to the need for automated management and network optimization objectives, ranging from automated service orchestration and provisioning, automatic service resilience and close-loop service adaptation to various challenges detected in the network such as faults/errors/failures/security-threats and performance degradations of various service impacting entities, and many more use cases autonomics innovators may envisage. The full spectrum of Self-* features for *self-management* functionality (e.g. *self-configuration*, *self-diagnosis*, *self-protection*, *self-optimization, self-awareness, etc*.) prescribed in ETSI TS 103 195-2 [i.5] and ETSI TS 103 194 [i.4] apply to the IMS environment as well. [i.17] provides additional insights on management operations in IMS that should be automated and can be dynamically adapted by way of closed-loop (autonomic) management and control software (i.e. the GANA autonomics enablers), and such aspects for automation by autonomics include planning related tasks, fulfilment related tasks, and assurance related tasks - i.e. all tasks that are normally achieved manually by human operators through OSS and NMS systems used for IMS operations.

NOTE: There is a lot of research work in literature on autonomics for IMS, and such research results can be exploited to implement GANA DEs and autonomics algorithms recommended in the present document on GANA instantiation onto IMS networks and functions. As such researchers can now Bring Research Results on Autonomics Algorithms for Dynamic IMS Services to implementing autonomic IMS products according to the ETSI Framework for implementing Autonomics in IMS presented by the present document. Examples of research work on autonomics for IMS are [i.15], [i.23], [i.24] and [i.29].

6 Instantiation of GANA Functional Blocks and Reference Points for Enabling Autonomic Management & Control of IMS Services in the IMS Architecture

6.1 Overview

The GANA reference model defines a framework and a structure guiding industries to plan, specify and design of the relevant Functional Blocks (FBs), which are specific to realize autonomicity, cognition, and self-management. Individual Functional Blocks could be seen as functional elements, or architectural components, performing certain functions. When talking about standardizable "autonomic behaviors" this refers to the fundamental behaviours of the Functional Blocks for autonomicity and self-management during the process of, e.g. *self-awareness and self-configuration* of Network Elements (NEs) in a plug and play fashion. This includes how the GANA DEs discover network entities and network objectives/goals, profiles, policies and data which they require for the configuration of the network elements and the network as a whole.

Examples of Requirements for NE/NF level autonomics (GANA DE Levels 2&3) in the IMS, based on similar cases on introducing lower autonomics in NE/NF in 3GPP architectures as described in ETSI TR 103 404 [i.38]:

- IMS Network Function (NF) Auto-Configuration and Adaptive Re-Configuration in response to detected or predicted situations
- IMS Function Resilience & Survivability
- IMS Function Security Management for Self-Protection and Self-Defense
- Energy Saving
- Signalling Optimization
- Monitoring Management

NOTE 1: There are other sources that describe various challenges in IMS that can be addressed by automated management and autonomic management and control operations by specific DEs instantiated into an IMS architecture as described in clause 6.5. For example, ETSI GS NFV-SEC 013 [i.22] that considers need for security autonomics in IMS. Another example, [i.17] discusses various management aspects for IMS that can be automated, and DE can play the role for automating the management aspects and dynamically re-configure the associated Managed Entities (MEs) in a closed-loop fashion based on various targets of the DE algorithms.

NOTE 2: The framework presented in the present document also serves to provide a blueprint on how to exploit research results on autonomics in IMS to implement the prescribed DEs and their autonomics algorithms.

6.2 High-Level View of the GANA Instantiation onto the IMS Architecture

The following diagram presents a block diagram of the overall picture on GANA instantiation onto the IMS architecture, with depiction of the GANA Functional Blocks (FBs), Reference Points (Rfps) of the GANA FBs, and the Hierarchical Framework of GANA DEs in the then autonomicity-enabled IMS architecture.

NOTE 1: On the NE/NF level (GANA Node Level 3) autonomics in IMS architecture, the GANA Node-Main-DE as defined in ETSI TS 103 195-2 [i.5] may be the level within an NE/NF that may be prioritized in enhancing the intelligence of the NE/NF function. But clause 6.5 provides more details on the kinds of GANA DEs that can be instantiated into the IMS architecture and implemented by innovators and implementers of DE and algorithms for autonomics.

NOTE 2: Each GANA DE is meant to bring its own value by virtue of its autonomics algorithms and operations it dynamically performs on it associated Managed Entities (MEs) and Management Objects (MOs), and to bring more value when combined with autonomics of other GANA DEs instantiated and implemented to operate in the targeted network architecture and its associated management and control architecture, such as the case of the IMS architecture.

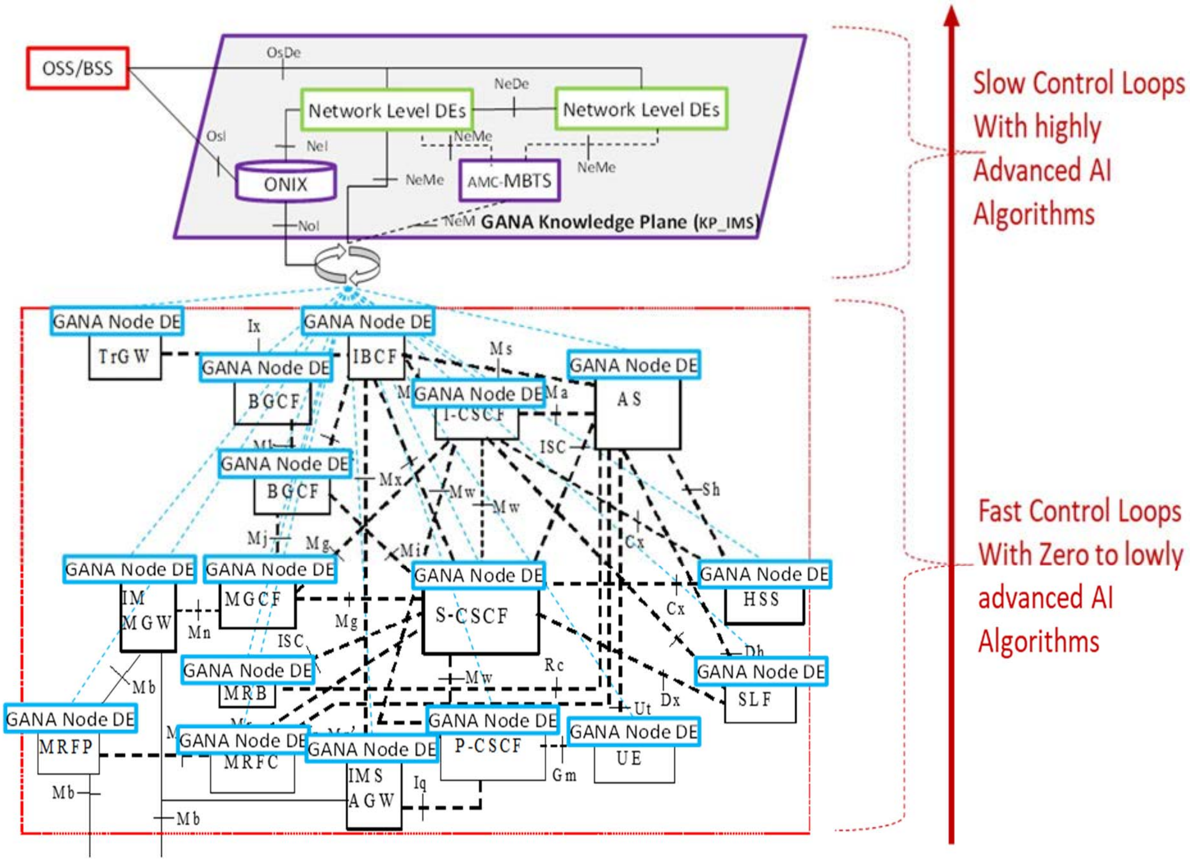

Figure 9: Block diagram of GANA instantiation onto the IMS architecture, GANA Decision Elements (DEs) in Autonomicity-enabled IMS Architecture

NOTE 3: More details on Instantiation of GANA DEs onto the IMS Architecture are provided in clause 6.5.

The following are examples of architectural scenarios for IMS deployments as observed in some industry implementations for IMS. Using the two scenarios (Scenario-1 and Scenario-2) as examples, there are Options that may be pursued in implementing GANA KP Platform(s) in IMS environment for Higher-Level Autonomics by higher level hierarchical GANA DEs at GANA Network Level 4 as illustrated below.

Figure 10 presents the Options that may be pursued in implementing GANA KP Platform(s) in IMS environment architecture Scenario-1, while Figure 11 presents the Options that may be pursued in implementing GANA KP Platform(s) in IMS environment architecture Scenario-2.

In both architecture scenarios for IMS deployments, examples of Autonomic (AMC) Operations that can be achieved by GANA KP Platforms individually and collaboratively are:

1) Automated service orchestration and provisioning(via Management and Control Systems such as OSS/BSS, SDN Controllers, MANO, etc.), automatic service resilience and close-loop service adaptation to various challenges detected or predicted in the network such as faults/errors/failures and/or security-threats/attacks/risks and/or performance degradations of various service impacting entities; This pertains to both IMS control services and Multimedia Flow Level Services.

2) Autonomic Functions Orchestrations or reconfiguration (within specific layer) based on resilience and survivability scenarios.

3) E2E SLAs Fulfillment and Assurance by the collaboration of the KP Platforms.

4) Security-Driven Autonomic Service Adaptation.

Meaning that each of the KPs may perform such autonomic operations in respect of the Functions of the Layer it is responsible for in a standalone manner and/or in collaboration with other KPs that provide it some data/information (e.g. KPIs) of relevance to the operations.

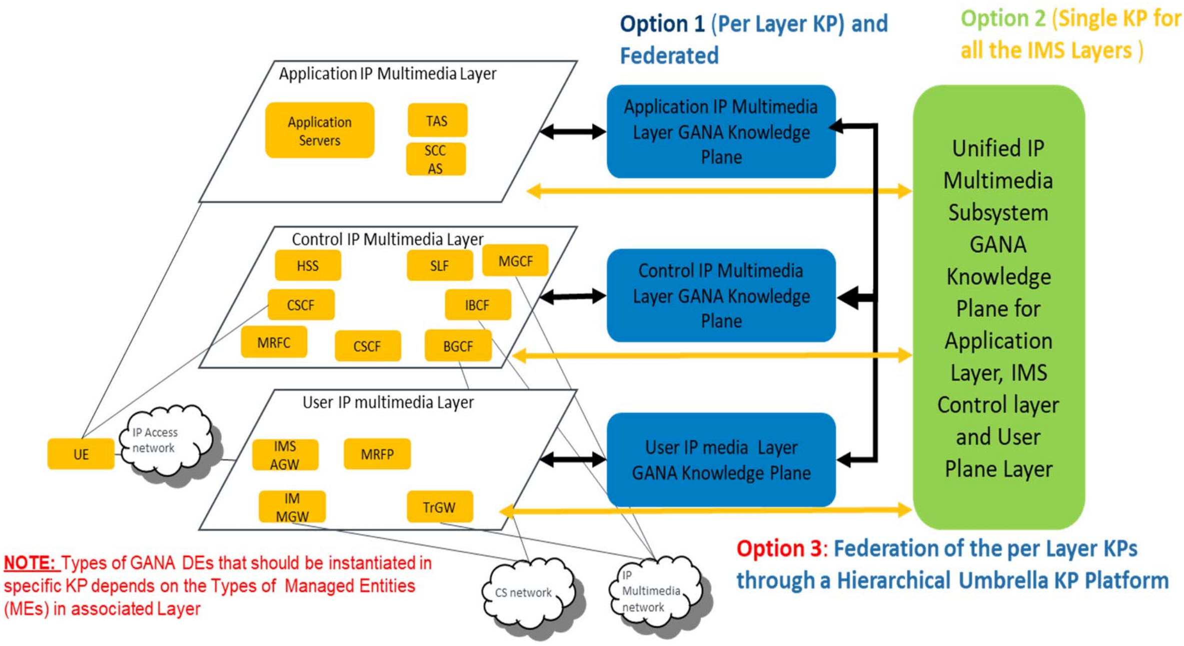

Figure 10: Options that may be pursued in implementing GANA KP Platform(s) in IMS environment architecture Scenario-1

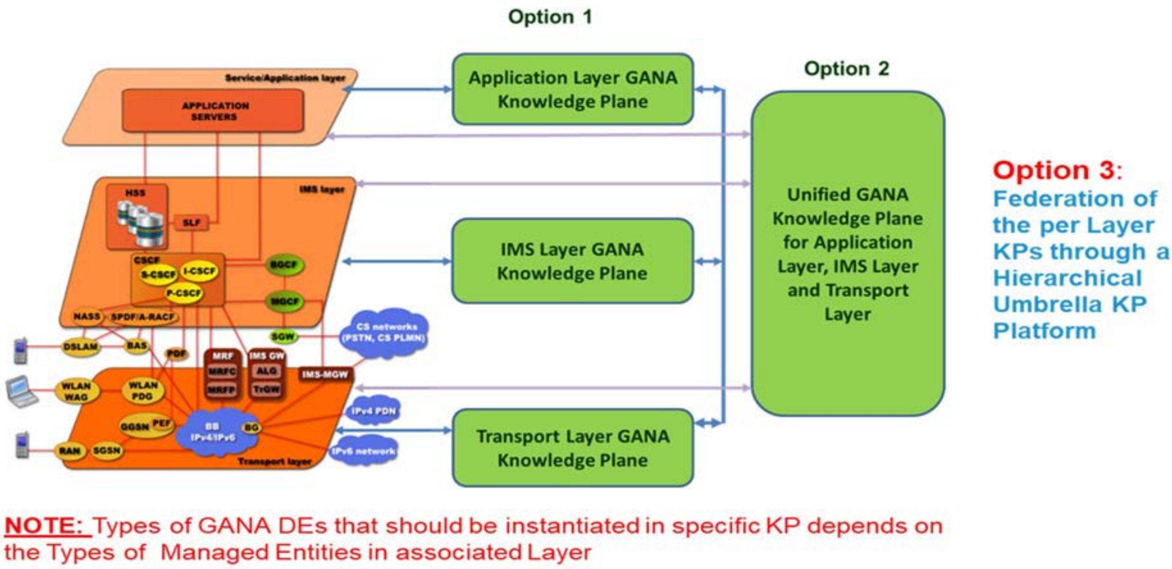

Figure 11: Options that may be pursued in implementing GANA Knowledge Plane (KP) Platform(s) in IMS environment architecture Scenario-2 that is based on IMS architectural scenario source presented by [i.44] that in turn is based on ETSI Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN) deliverable ETSI ES 282 001 [i.48]

NOTE 4: In **Option-1**, the Application Layer GANA KP, the IMS Layer GANA KP and Network Layer Segment-specific GANA KP (i.e. Transport Layer GANA Knowledge Plane(s)) need to be synchronized in the way they program certain functions through the OSS if the OSS is a shared OSS/NMS that integrates with the GANA KPs. The common integration points for the GANA KPs and the OSS/NMS need to be taken into consideration in determining how the KPs synchronize on reacting to events reported by the OSS(s)/NMS(s) and also determining how the GANA KPs synchronize in sending commands to the OSS/NMS that in turn configure the underlying IMS functions and network resources and parameters. While Root-Cause-Analysis (RCA) by Alarm correlations may be performed on the OSS/NMS and the results shared with the GANA Network-Level Fault-Management-DE(s) in the KP(s) in order for the GANA KP DEs to plan a set of actions for performing self-repair or self-healing of faulty entities, RCA may also be performed by the GANA Network-Level Fault-Management-DE(s) in the KP(s) - depending on the deployment scenario that takes into account the umbrella OSS/NMS capabilities and capabilities of the specific GANA KP(s) that should be integrated with the OSS/NMS. EMS level correlations also need to be taken into considerations as GANA KP(s) may need to be integrated with each management and control system in order to have full visibility on some events and selectively (re)-program the network functions and resources through the system best suited for use and the target objective as described in ETSI TS 103 195-2 [i.5] and in ETSI 5G PoC White Paper No.2 [i.18].

The following diagram illustrates key components that may all be involved in playing a role in delivering Autonomic (Closed-Loop) Security Assurance and Service Assurance of Network Services:

- GANA Knowledge Plane for a specific network segment(s);
- SDN-Driven Programmable Traffic Monitoring Fabrics;
- Network Elements (PNFs/VNFs);
- Traffic Monitoring Probes;
- Data Collectors;
- NMs/EMs (Network Managers/Element Managers);
- PMs (Performance Managers);
- FMs (Fault-Managers);
- Automated Test System for Orchestrated Assurance and SLA Violations Detection;
- SDN Controller Framework for the production network;
- OSS;
- Configuration Management Tools that complement an OSS that may be in place or are deployed to play a role that in some cases is simply played by an OSS platform that covers the full spectrum of Fault, Configuration, Accounting, Performance and Security (FCAPS) functions;
- Service and Domain Orchestrator systems.

The diagram below (Figure 12) is a general picture, while the subsequent diagram (derived from the general picture presented in Figure 12) that follows thereafter define the scope of focus for Demo-3 performed in the ETSI 5G PoC project [i.16] (see https://intwiki.etsi.org/index.php?title=Accepted_PoC_proposals).

NOTE 5: In terms of diversity of data and event sources of a GANA KP implementation and also the diversity of management and control systems through which the GANA KP DEs can be designed to execute autonomic operations that (re)-program the resources, parameters and services of the underlying network infrastructure(s) via the northbound interfaces exposed by such systems, a Telco Cloud environment and its NFV environment (including associated MANO stack) should also be considered in integration with a GANA KP as illustrated in Figure 12.

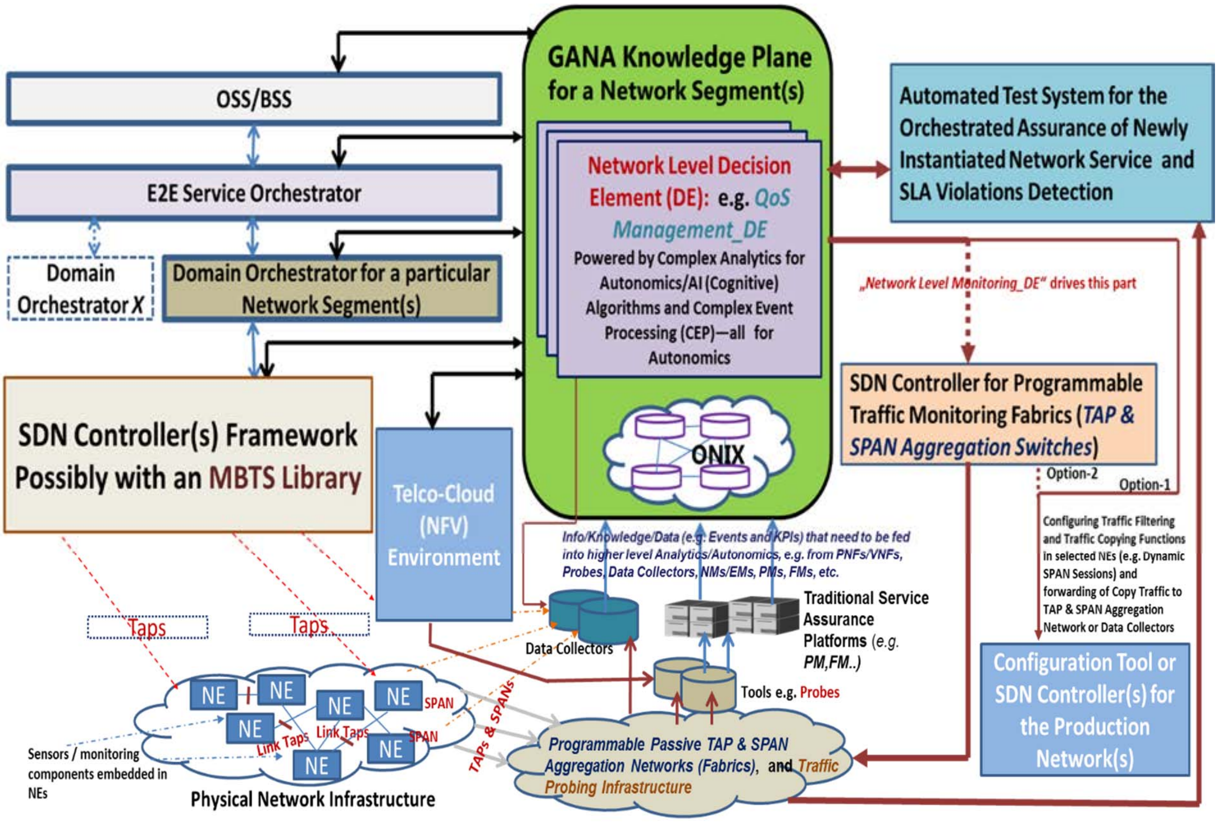

Figure 12: Generic High-Level Picture on Key Components for Autonomic Management and Control Operations (e.g. Autonomic Service Assurance) for Network Services (e.g. 5G Network Slices), Components' interactions and Data Sources (including Event Sources)

An illustration of a GANA Knowledge Plane for the Transport Network is shown below in Figure 13, to illustrate the Architecture and Role of the GANA KP for the Transport Network (e.g. Front-haul, Mid-haul and Backhaul, or X-Haul) in Autonomic Service Assurance. Figure 13 captures the integration of several components that play specific roles in autonomic service and security assurance of network services (including IMS services):

- GANA Monitoring DE in the GANA KP Platform (i.e. the Network Level Monitoring DE).
- SDN Controller for Programmable Traffic Monitoring Fabrics (TAP & SPAN Aggregation Switches).
- Programmable Passive TAP & SPAN Aggregation Networks (Fabrics).
- Automated Test System for Orchestrated Assurance and SLA Violations Detection on a newly instantiated service (e.g. a newly instantiated VNF or service chain involving multiple network functions).
- Configuration Tool or SDN Controller(s) for the Production Network(s).

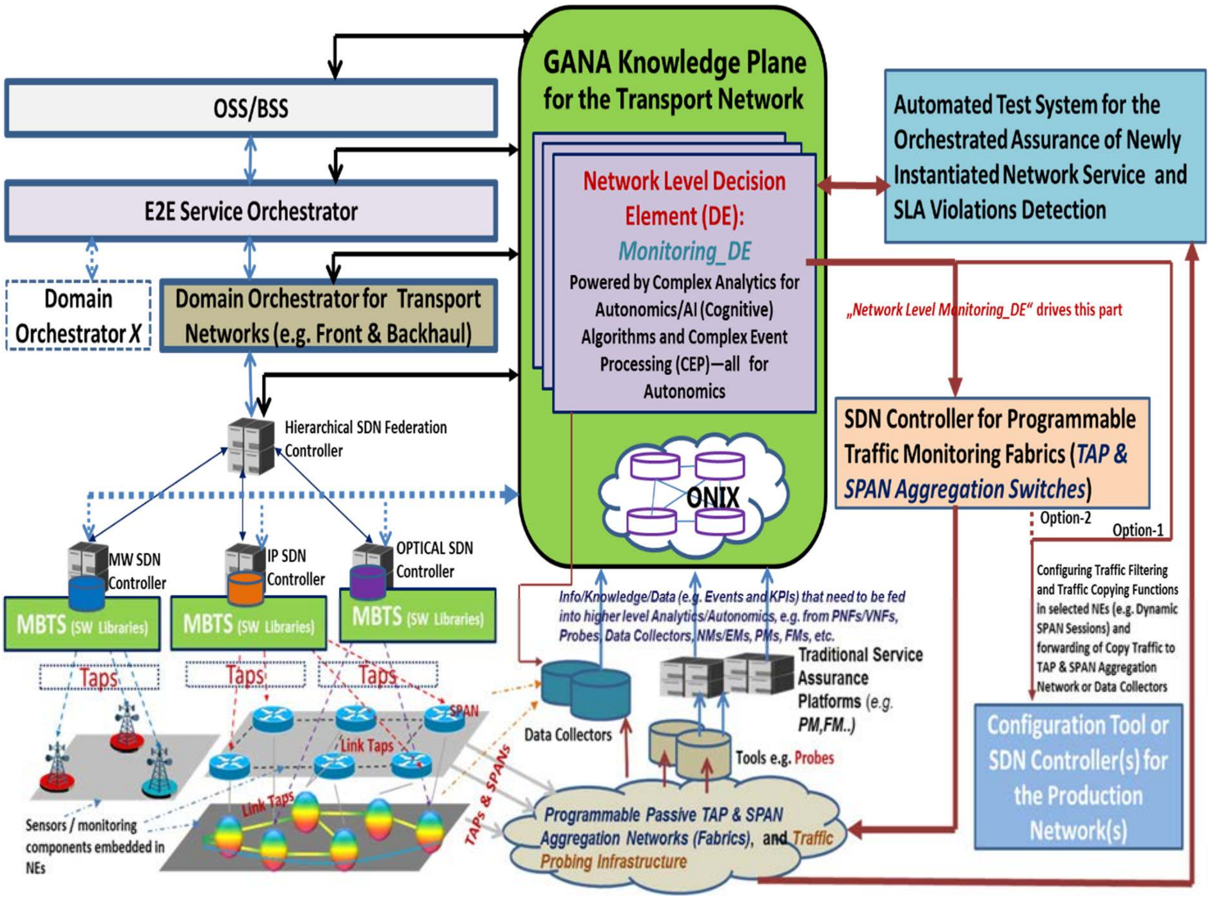

Figure 13: The roles played by the GANA Monitoring Decision Element (DE) in the GANA KP, SDN Controller for Programmable Traffic Monitoring Fabrics, and other components

NOTE 6: In reference to Figure 13, the following components also play some roles in their integration with a GANA KP Platform:

- Programmable Passive TAP & SPAN Aggregation Networks (Fabrics).
- Automated Test System for Orchestrated Assurance and SLA Violations Detection.
- Configuration Tool or SDN Controller(s) for the Production Network(s).

NOTE 7: ETSI TR 103 404 "GANA onto 3GPP Backhaul and Core Network" [i.38] elaborates the need for Collaboration of Knowledge Planes for E2E (End-to-End) Self-Optimization across various Network Segments.

NOTE 8: The autonomics implemented for each particular GANA KP designed for a specific network segment (e.g. KP for Multi-Access Network segment, or KP for Transport Network segment, or KP for Core Network Segment) act upon events and performance and service delivery challenges related to the associated network segment, to dynamically (re)-program the network functions and resource parameters so as to achieve targets such as fulfilling Service Level Agreements (SLAs). To achieve E2E Service Assurance and Self-Optimization Objectives GANA KPs for the specific network segments (including the IMS layer) should be federated to perform E2E correlations of events and state and collaboratively to realize Holistic Multi-Domain State Correlation and resources programming by the GANA KPs for the network segments/domains such as the Access, X-Haul Fronthaul, Midhaul and Backhaul), and Core Networks, etc. as described in ETSI 5G PoC White Paper No.3 [i.16], ETSI 5G PoC White Paper No.1 [i.17], ETSI 5G PoC White Paper No.2 [i.18].

NOTE 9: Clause 7.2 provides insights on Other Kinds of Data/Information that can be fed into GANA KP Platforms in Driving Autonomics for IMS Services.

6.3 IMS Traffic Monitoring Architecture, Monitoring Data and KPIs Data Feeds into the GANA KPs for E2E Closed-Loop (Autonomic) Service & Security Assurance

This present clause provides insights on how a GANA KP Platform, including an IMS Layer GANA Knowledge Plane (KP) Platform and a Transport Layer GANA Knowledge Plane (KP) Platform, can be integrated with Traffic Monitoring and Passive Probing Solutions that can feed the KP with various kinds of data such as the following data:

- KPIs data obtained from the Analytics performed by Traffic Analyser Tools such as Probes that receive Traffic from an Out-Of-Band (OOB) Visibility Network that forwards copies of traffic copied from the production network using TAPs and SPAN methods. ETSI 5G PoC White Paper No.3 [i.16] and the associated PoC Demo-3 (available at https://intwiki.etsi.org/index.php?title=Accepted_PoC_proposals) provide useful insight on this subject as part of the broader picture on "Programmable Traffic Monitoring Fabrics that enable On-Demand Monitoring and Feeding of Knowledge into the ETSI GANA Knowledge Plane for Autonomic Service Assurance of 5G Network Slices; and Orchestrated Service Monitoring in NFV/Clouds". While ETSI 5G PoC White Paper No.6 [i.28] also provides useful insights on on-demand monitoring.

- Telemetry data from NEs/NFs.

NOTE 1: Clause 7.2 provides insights on Other Kinds of Data/Information that can be fed into GANA KP Platforms in Driving Autonomics for IMS Services.

Figure 14 illustrates how a GANA KP Platform can be integrated with various Data and Event Sources and Traffic Monitoring and Passive Probing Solutions in a Physical Environment that can feed the KP with various kinds of Data (e.g. Events Data), and the following aspects are complementarily reflected by Figure 14:

- Through the SDN Controller (s) for the TAP & SPAN Aggregation Network as illustrated later in clauses 6.2 and 6.3 and in ETSI 5G PoC White Paper No.3 [i.16], the KP DEs (particularly the Monitoring-DE) can trigger the SDN Controller to configure SPAN Sessions on-demand via SDN Controller for the Production Network to force copied traffic to flow to an Out-Of-Band (OOB) that is programmable by the SDN controller for the OOB to forward traffic to various Analytics Tools in the Centralized Analytics Tools Farm (e.g. Probes and Security Analytics Tools). ETSI TS 103 195-2 [i.5] provides insights on how the GANA KP Monitoring-DE (Network Level Monitoring DE) in the GANA KP Platform can be implemented.

- There are other systems that can serve as Data Sources of the GANA KP Platform, e.g. PM (Performance Management system) and FM (Fault Management system) for Network and for IT (Information Technology) environments; NEs/NFs.

- The GANA KP Platform may need to send some messages to the components and systems such as the ones indicated on Figure 14. For example, the GANA KP DEs such as the GANA KP Security Management-DE need to integrate with Ticketing Systems to consume events from the ´Ticketing Systems. The GANA KP Security Management-DE may be interested in events that may be linked to security attacks incidents and use such events to compute and apply self-defense strategies for the network (the concept of self-defense is covered in more details in clause 6 of ETSI TC INT AFI 5G PoC White Paper No.6 [i.28]). When a problem linked to a particular security incident related Ticket has been resolved and fixed by the GANA KP as a whole, the Ticket is then cleared by the GANA KP Security Management-DE as Dynamic Updates on Tickets Resolutions/Clearance by GANA KP DEs, i.e. the DE accesses the Ticketing System to clear the Ticket if the problem has been found and fixed by the GANA KP.

- A human Service & Network Troubleshooter needs to primarily interface with GANA KP Platform for certain needs linked to Service and Network Troubleshooting in case the GANA KP is operating in an *"Open-Loop" Mode* and the human in the loop is required during troubleshooting scenarios. The human user may choose to interact with the components marked as "Secondary Service Troubleshooting Position".

NOTE 2: ETSI GS NFV-SEC 013 [i.22] provides very useful insights on IMS Network Monitoring, including Security Monitoring of the IMS Network (with illustration using IMS core network security monitoring).

Figure 14 illustrates how a GANA KP Platform can be integrated with various Data and Event Sources and Traffic Monitoring and Passive Probing Solutions that can feed the GANA KP with various kinds of Data, e.g. Events Data. The Scenario considered in Figure 14 is one involving a *Physical IMS Network Implementation* (in contrast to Virtualized IMS Implementation using NFV technology, i.e. vIMS) for a Mobile Network (IMS Mobile).

NOTE 3: As illustrated on Figure 14, in general, GANA KP platforms' DE algorithms require to create actionable insights from various kinds of data from other data and event sources as described earlier and in ETSI 5G PoC White Paper No.4 [i.26] and ETSI 5G PoC White Paper No.5 [i.27].

NOTE 4: The integration framework shown in Figure 14 below is based on the architecture scenario presented in Figure 11, and similar integration framework can be derived for the architecture scenario in Figure 10 or other scenarios. In Figure 14 below, Transport Layer KP is based on the architecture scenario presented in Figure 11. Transport Layer elements in the Figure 14 below also include X-Haul transport network type of network elements/functions (NEs)) as discussed earlier concerning Transport Network GANA KP, which ought to be different and separate from Core Network GANA KP . Meaning that ideally what is indicated as Transport Layer GANA KP should be split into Transport Network GANA KP and a Core Network GANA KP. Where the GANA KP(s) implementation option is one based on the Options1-3 described earlier, GANA KPs Platforms, from Access Network GANA KP, Transport Network KP, Core Network KP, User IP Media Layer KP, IMS Layer KP and Application Layer KP should be federated in such a way that they can exchange information (including state info and events) and collaboratively drive E2E Autonomics across the domains and layers, as illustrated by the big picture in ETSI 5G PoC White Paper No.1 [i.17], ETSI 5G PoC White Paper No.4 [i.26] and ETSI 5G PoC White Paper No.6 [i.28].

NOTE 5: Regarding IMS KPIs that should be accessible (fed) to the IMS Layer GANA KP Platform(s), sources such as ETSI TS 132 454 [i.21] provide definitions of various IMS KPIs that can be used by the GANA KP Platform for its autonomic operations, which include dynamic resource provisioning and orchestration and provisioning of IMS services as driven by challenges experienced in the network or predictions of the GANA KP on failure scenarios and service degradations for certain IMS service flows. There are other KPIs that may be of interest to the IMS Layer GANA KP Platform and its GANA KP DE algorithms and decisions-making intelligence, such as VoLTE, VoWiFi, and Rich Communication Services (RCS) related KPIs. Such KPIs may be exchanged between the IMS Layer GANA KP Platform and other KPs such as the Transport Layer GANA KP Platform and Application Layer KP Platform, because each KP for a specific layer is the one primarily required to keep track of KPIs associated with its layer and the KPIs may be required by DE algorithms of the other KPs. There are various insightful sources where some KPIs that may be of interest to KPs are defined, e.g. ETSI TS 132 409 [i.49], ETSI TS 132 454 [i.21], Recommendation ITU-T G.1028 [i.50] and other sources.

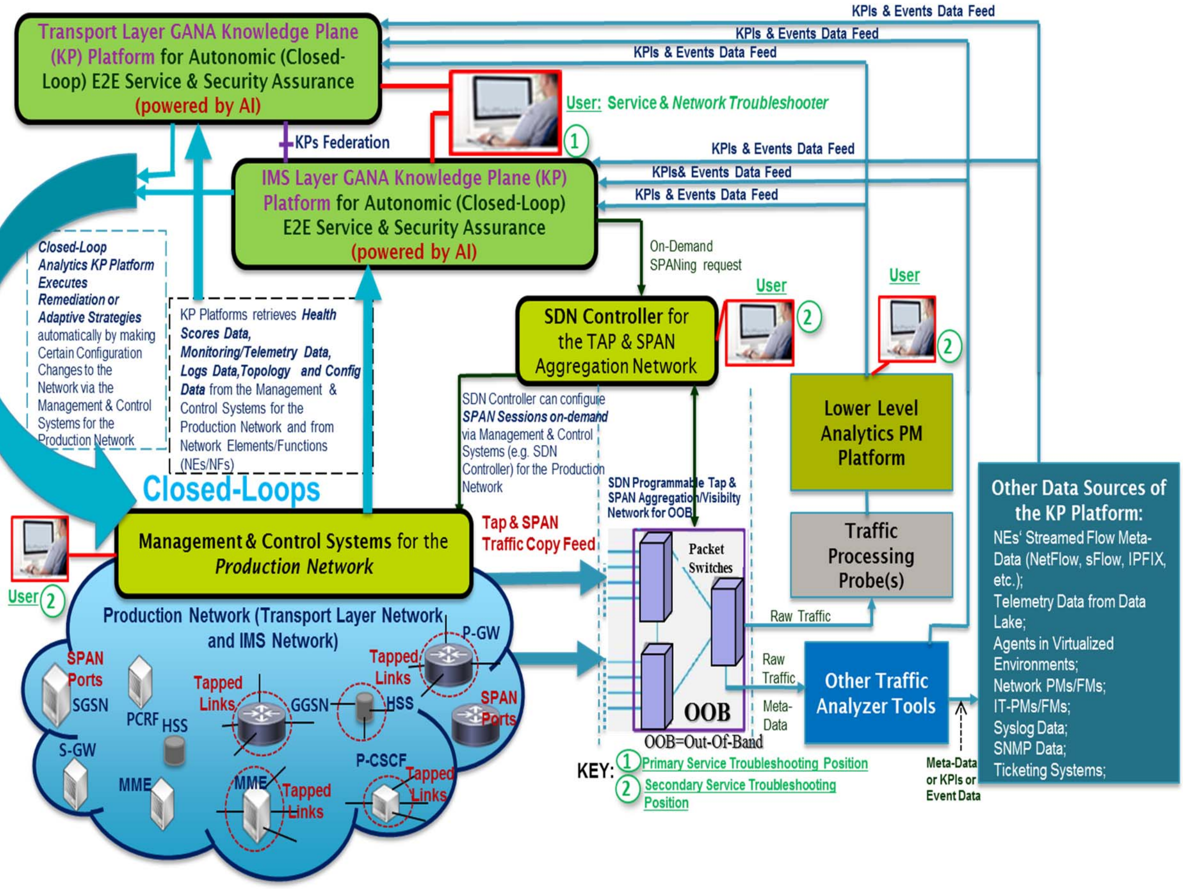

Figure 14: How a GANA KP Platform can be integrated with various Data and Event Sources and Traffic Monitoring and Passive Probing Solutions in a Physical Environment that can feed the KP with various kinds of Data (e.g. Events Data)

The Scenario considered in the following Figure 15 is one involving a ***Virtual IMS (vIMS) Network Implementation*** (in contrast to Physical IMS Implementation using PNFs, i.e. vIMS) for a Mobile Network (IMS Mobile). There are two approaches to network and service performance monitoring in Telco-Clouds environments (NFV environments) as discussed in various sources in literature, namely:

1) Use of Virtual TAPs (vTAPs) or Agents installed in the NFV Host environment hosting the vIMS VNFs to copy traffic involving communications between VNFs and sending it out of the Host to some Probe or Analyser outside of the NFV environment where Analytics is performed on the traffic, and then results of such analytics (e.g. KPIs) can be communicated to the GANA KP responsible for the Telco Cloud environment, e.g. the IMS Layer GANA KP Platform (the KP itself can also be virtualized).

2) Use of Virtual Probes (vProbes) as Agents installed in the NFV Host environment hosting the vIMS VNFs to copy and directly analyse traffic involving communications between VNFs and sent out of the Host the results of such analytics (e.g. KPIs) to the GANA KP responsible for the Telco Cloud environment, e.g. the IMS Layer GANA KP Platform (the KP itself can also be virtualized).

NOTE 6: ETSI GS NFV-SEC 013 [i.22] and ETSI GS NFV-REL 004 [i.20] discuss various approaches to monitoring in NFV environments (with illustration of IMS Network Monitoring), while [i.25] discusses such approaches to monitoring (probing) in vIMS environments.

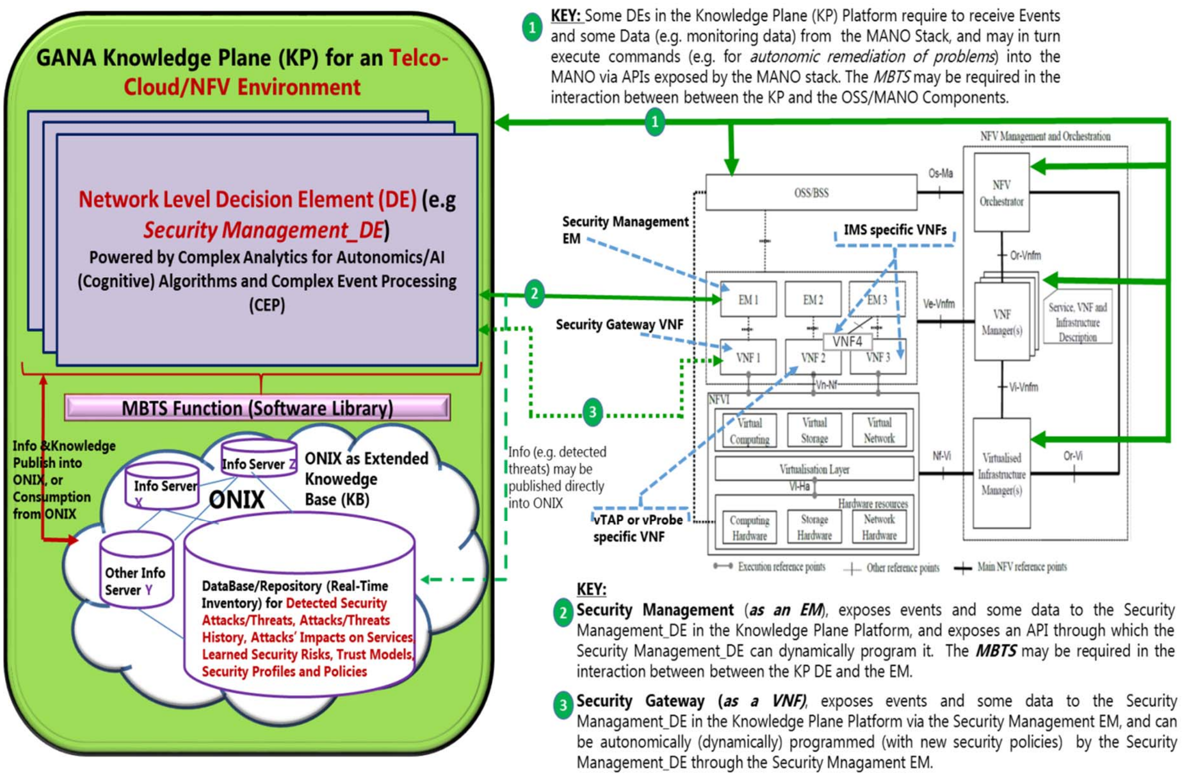

Figure 15: How a GANA KP Platform can be integrated with various Data and Event Sources and Traffic Monitoring and Passive Probing Solutions in a Telco-Cloud/NFV Environment that can feed the KP with various kinds of Data (e.g. Events Data)

NOTE 7: ETSI 5G PoC White Paper No.6 [i.28] presents illustration of certain vendor capabilities concerning how a GANA KP Platform can be integrated with various Data and Event Sources and Traffic Monitoring and Passive Probing Solutions in a Telco-Cloud/NFV Environment (e.g. an IMS Layer Telco Cloud) that can feed the KP with various kinds of Data (e.g. Events Data such as Security Threats or Attacks detected in an environment (including Telco-Clouds). While ETSI GS NFV-SEC 013 [i.22] provides useful insights on the subject of Security Monitoring in NFV environments and those approaches presented in ETSI GS NFV-SEC 013 [i.22] can be integrated with the GANA Framework's principles.

NOTE 8: For both cases presented by Figure 14 and Figure 15, clause 7.2 provides insights on Other Kinds of Data/Information that can be fed into GANA KP Platforms in Driving Autonomics for IMS Services.

6.4 GANA KP(s) Analytics Driven (Re)-Orchestrations and Provisioning of IMS Services by the IMS Layer GANA KP

Regarding IMS KPIs that should be accessible (fed) to the IMS Layer GANA KP Platform, sources such as ETSI TS 132 454 [i.21] provide definitions of various IMS KPIs that can be used by the IMS GANA KP Platform for its autonomic operations, which include dynamic resource provisioning and orchestration and provisioning of IMS services as driven by challenges experienced in the network or predictions of the IMS GANA KP on failure scenarios and service degradations for certain IMS service flows. Challenges such as detected security threats or attacks may considered in the design of IMS GANA DE algorithms that the cause changes to the way an IMS service is delivered, or may cause new IMS specific VNFs to be orchestrated and provisioned in the IMS Layer Telco-Cloud to deliver services as part of self-defense strategy by the IMS Layer GANA KP Platform. ETSI 5G PoC White Paper No.6 [i.28] discusses various aspects linked to *self-protection and self-defense* autonomic behaviours that should be considered by implementers of Security Management-DEs of a GANA KP Platform. ETSI GS NFV-SEC 013 [i.22] also provides useful insights on security problems that can be detected or predicted in an NFV environment that can be addressed by GANA KP DE algorithms and autonomic operations within the telco cloud where IMS could be orchestrated. While some challenges related to degraded performance that jeopardizes SLAs may result in lower level autonomics implemented at NFVO, VNF-Manager or VIM to react by performance problems reported by virtual probes (agents) or other probing and analytics means by collaboratively scaling up resources required to improve performance of IMS VNFs.

NOTE 1: ETSI TR 103 404 [i.38] provides insights on KP Federations that should be considered in adding to that picture of KP federations the GANA KP(s) for IMS layers. ETSI TR 103 473 [i.9] also provides insights on the GANA KP Platforms in the BroadBand Forum (BBF) Architecture Domain with consideration for the federation of such KP platform with that for a 3GPP Architecture Domain. The GANA KP for a virtualized IMS (or even for the non-virtualized case) needs to be considered in adding to that picture of KPs federations discussed in ETSI TR 103 473 [i.9] and ETSI TR 103 404 [i.38].

ETSI 5G PoC White Paper No.6 [i.28] demonstrates how the ETSI GANA Framework provides principles that guide implementers of Autonomic Security Management and Control Components to take into consideration in the interaction of such autonomic manager components with other ***Autonomic Management and Control components*** such as autonomic manager components for ***Autonomic Quality-of-Service(QoS) Management, Autonomic Monitoring Management, etc. That enables to implement various scenarios for collaborative AMC intelligence by the various AMC Components (i.e. GANA DEs), such as Security requirements based Autonomic (dynamic) QoS Dynamic Provisioning; Security requirements driven adaptive(autonomic) monitoring and analytics of certain types of network traffic flows in the network; Security requirements based Autonomic (dynamic) Mobility Management, etc.*** Various KPIs and Events specific to IMS service delivery may be used in re-orchestration and provisioning of IMS services collaboratively by GANA DEs in the various KP Platforms introduced into the IMS Architecture as described earlier in the present document. Also, innovators of autonomics in IMS may implement intelligence by which GANA KP QoS-Management-DE and GANA KP Security-DE collaboratively perform dynamic provisioning of IMS services based on scenarios like failure scenarios or QoS degradations or security attacks or threats detections or predictions concerning parts of the IMS network or the underlying transport layer networks.

NOTE 2: Clause 7.2 provides insights on Other Kinds of Data/Information that can be fed into GANA KP Platforms in Driving Autonomics for IMS Services.

NOTE 3: There is a lot of research work in literature on autonomics for IMS, and such research results can be exploited to implement DEs and autonomics algorithms recommended in the present document on GANA instantiation onto IMS networks and functions. Examples of research work on autonomics for IMS are [i.15], [i.23], [i.24] and [i.29].

6.5 Instantiation of GANA Decision Elements (DEs) onto the IMS Architecture

6.5.1 Overview

The GANA Reference Model is an agnostic (generic) framework when it comes to the target implementation-oriented network architecture onto which it can be instantiated, and it is described in a technology independent way. Figure 9 illustrates the instantiation of GANA onto IMS network architecture including the definition of the GANA Functional Blocks (FBs) for the GANA instantiation onto IMS architecture, as well as the interconnections between particular GANA DE hierarchy levels for abstraction of self-management functionalities and their associated control-loops for AMC operations at the particular levels of multi-layer autonomics. The key DEs that can be introduced into the IMS the architecture are represented by blue boxes in Figure 9.

Specific IMS functionalities of selected DEs at the ***Function, Node and Network GANA Levels*** are presented in Table 1.

NOTE 1: While considering the DEs instantiated in this clause of the present document, GANA Levels 2 and 3 DEs instantiated to operate in specific NEs/NFs of the IMS network and their KP level "mirror DEs", from an implementation point of view there are two Scenarios or Options that could be pursued as indicated below and as described earlier in the introduction clause of the present document:

1) GANA allows for the implementer to either implement autonomics through "centralized DE algorithms" in the GANA KP Platform Level only and/or choosing to implement some DE algorithms as "distributed DE algorithms" that involve GANA levels 2 or 3 DEs communicating horizontally within the NEs/NFs of the network (for a certain scope within the network) to realize "in-network self-management and control". A top down approach may be taken, , whereby the implementers start with focusing on implementing the Outer Loop(s) (i.e. the "Slow Control-Loops") by the GANA KP Platform that relies on Telemetry Consumption from the IMS functions, and then the Knowledge Plane driven Autonomic outer loop can be complemented step-by-step by injecting some DEs into certain NEs/NFs of the IMS architecture that still need to be policy-controlled by the DEs of the logically centralized GANA KP (the slow control loops). That means the focus may be on implementing only the GANA KP level autonomics without introducing GANA levels 2 and 3 autonomics in the IMS functions (NEs/NFs), i.e. leaving the IMS functions without any autonomics intelligence for local and "fast-loop" reactions. This option means the implementer of the autonomics is relying only on the centralized GANA KP DE algorithms to implement outer-loop autonomics over the IMS functions of the network by relying on the IMS functions having to stream telemetry and events to the GANA KP and possibly to a Data Lake, while the IMS functions have no local autonomics implemented within. The drawback of not having the "fast control-loop" autonomics is described in ETSI White Paper No.16 [i.14] and in ETSI TS 103 195-2 [i.5]. In addition to achieving fast local reaction, embedding autonomics in the NEs/NFs helps reduce the need to send or stream huge amount of telemetry data to the GANA KP or a Data Lake by having the NE/NF level autonomics send only aggregate reports to the GANA KP that still should policy control the NEs/NFs, while the "autonomic NE/NF" can still send out selected (reduced) telemetry data to the GANA KP Platform.

2) The other scenario is one that considers a hybrid implementation of the GANA KP level autonomics (Slow Control-loops (GANA Level 4 autonomics)) and NE/NF level autonomics (GANA levels 2 and 3) in the IMS functions, though a top down approach to implementing the "Macro-Level" autonomics in the KP Platform(s) first and then complementing with "Micro-Level" autonomics in the NEs/NFs themselves, can be pursued.

NOTE 2: Clause 4.4.6 "Implementation Guide for GANA DEs" of ETSI TS 103 195-2 [i.5] provides insights on how DEs may be implemented, either as standalone processes at run-time or merged as a single process, particularly DEs instantiated within an NE/NF (GANA node), i.e. within an IMS function. Clause 4.4.6 "Implementation Guide for GANA DEs" of ETSI TS 103 195-2 [i.5] provides an illustration of possible approach to implementing GANA Levels 2, 3 and 4 DEs at run-time.

NOTE 3: While Table 1 below provides insights on Types of GANA DEs that can be introduced to operate as software components within IMS Functions (Nodes) and/or in the KP Level, with characterization of the Managed Entities (MEs) that each DE owns and dynamically/adaptively manages in closed-loop (autonomic) fashion in order to fulfil certain targets based on context changes and state of network and resources, in general, DE implementers should consider that the Types of GANA DEs that should be instantiated in a specific GANA KP depends on the Types of Managed Entities (MEs) in the associated Layer the KP is responsible for (see clause 6.2). Also, DE implementers should consider that the Types of GANA DEs that should be instantiated in a specific IMS Function depends on the Types of Managed Entities (MEs) in the specific IMS Function. Managed Entities (MEs) may have some Management Objects (MOs) defined and associated with them.

Table 1: Generic Specific IP Multimedia functionalities hosted by an IMS Function that should be autonomically managed by specific GANA DEs at Levels 2, 3 and 4

IMS Entity	GANA Level	DE type	Specific IMS functionality that should be autonomically (dynamically and adaptively) managed by the corresponding Decision Element (DE) software
IMS Function (as a GANA Node)	Function	Monitoring-DE	Monitoring-DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of monitoring services required of the IMS Function (Node) and configures the dissemination of monitoring data to consumers within the Node and outside. It configures and manages passive and active measurements on the different interfaces of the IMS function as may be required. Provides cross-layer measurements to support self-management QoS management, routing, forwarding management functions of the IMS Function (Node).
IMS Function (as a GANA Node)	Function	Data Plane & Forwarding Management-DE	The DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of the Data-Plane and Forwarding behaviours and policies to forward control (SIP) or media (RTP) to next hop (I-CSCF/PSTN/IBCF) with load balancing/security and Resilience_& Survivability-DE considerations. Node level Security Management-DE and Resilience_& Survivability-DE could interact with this function level DE.
IMS Function (as a GANA Node)	Function	Application & Service Management-DE	The DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of the different capabilities of the services functions/components needed to be used in the node to deliver services, and so this DE may be present only in nodes of Application Layer that should be under the management and control responsibility of the Application Layer GANA KP Platform.
IMS Function (as a GANA Node)	Function	Mobility Management-DE	The DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of the mobility mechanisms and protocols in the UE, the access network and at services level. This DE should be under the management and control responsibility of the Application Layer GANA KP Platform in particular the Application Server - Service Centralization and Continuity (AS-SCC) Mobility management DE.
IMS Function (as a GANA Node)	Function	QoS-Management-DE	The DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of QoS provisioning protocols and mechanisms to ensure quality for signalling (SIP) and multimedia streaming/voice (RTP) call in the node. In addition, the DE may also use any data/information that may be useful for closed-loop reaction of the DE in attempt to fulfil certain objectives local to the DE or global objectives targeted by the collaboration of all the DEs (logics) instantiated in the node. The DE is also policy controlled by the Network-Level QoS-Management-DE in the logically centralized KP Platform (see Table 3 in ETSI TS 103 195-2 [i.5]).
IMS Function (as a GANA Node)	Node	Security-Management-DE	The DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of the security of the IMS function (node) to realize self-protection and self-defense behaviours of the node.
IMS Function (as a GANA Node)	Function	Routing-Management-DE	Not Applicable to IMS relay on IP-CAN as routing is realized by the IP-CAN. The Routing-Management-DE when introduced in an IP-CAN Routing Node, the DE is responsible for orchestration and dynamically adaptive (closed-loop) management and control of routing protocols and mechanisms of the node hosting routing capabilities (protocols and mechanisms).

IMS Entity	GANA Level	DE type	Specific IMS functionality that should be autonomically (dynamically and adaptively) managed by the corresponding Decision Element (DE) software
IMS Function (as a GANA Node)	Node	Fault-Management-DE	The DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of Fault Detection Mechanisms, Fault Isolation/Localization/Diagnosis Mechanisms, Fault Removal Mechanisms.
IMS Function (as a GANA Node)	Node	Resilience & Survivability-DE	The DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of Proactive and Reactive Resilience Mechanisms, Survivability Strategies and Algorithms, Restoration and Protection Mechanisms. E.g. building of a new IMS function chain which could handle user session without any disruption.
IMS Function (as a GANA Node)	Node	Auto-Configuration & Auto-Discovery DE	The DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of neighborhood discovery, secure peer establishment, addressing, service management, fetching of Configuration Profiles and Policies specified by the Operator.
IMS-unified GANA KP	Network	Auto-Configuration & Auto-Discovery DE	The GANA KP DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of configuration changes required for each IMS function/nodes (particularly the internal DEs), by providing Configuration Profiles and Policies specified by the Operator through the Auto-Configuration & Auto-Discovery DE of a Node, which in turn dispatches configurations to any local DEs. It realizes the outer slow control loop that pertains to adaptive tuning of configuration changes behaviours in the IMS network. Its policy-controls the "mirror Auto-Configuration & Auto-Discovery DEs" that may be available at the node levels.
IMS-unified GANA KP	Network	Monitoring-DE	The GANA KP DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of Analysing/learning/reasoning on long term data measurements (e.g. link stability assessments that help in correct IP-CAN access selection or proper codec management to avoid disruption). It realizes the outer slow control loop that pertains to adaptive tuning of monitoring behaviours in the IMS network. Its policy-controls the "mirror Monitoring-DEs" that may be available at the node levels.
IMS-unified GANA KP	Network	Data Plane & Forwarding Management-DE	The GANA KP DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of Data Plane and Forwarding behaviour (in collaboration with the Routing Management-DE as may be necessary), and the DE realizes the slower control loop to use wider global knowledge required in addressing the problems affecting the forwarding behaviours. It realizes the outer slow control loop that pertains to adaptive tuning of Data Plane and Forwarding behaviours in the IMS network. It policy controls the "mirror Data Plane & Forwarding Management-DEs" that may be available at the node levels.
IMS-unified GANA KP	Network	Generalized Control Plane Management-DE	The GANA KP DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of control plane protocols and mechanisms. It realizes the outer slow control loop that pertains to adaptive tuning of control plane protocols behaviours in the IMS network. Its policy-controls the "mirror Generalized Control Plane Management-DEs" that may be available at the node levels.

IMS Entity	GANA Level	DE type	Specific IMS functionality that should be autonomically (dynamically and adaptively) managed by the corresponding Decision Element (DE) software
IMS-unified GANA KP	Network	QoS-Management-DE	The GANA KP DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of the QoS provisioning protocols and mechanisms to ensure quality for signalling (SIP) and multimedia streaming/voice call (RTP) in the network, in collaboration, as may be necessary, with the Routing Management-DE that manages and controls routing protocols and mechanisms. It realizes the outer slow control loop that pertains to adaptive tuning of QoS management behaviours in the IMS network. Its policy controls the "mirror QoS-Management-DEs" that may be available at the node levels.
IMS-unified GANA KP	Network	Security-Management-DE	The GANA KP DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of Security Protocols, Algorithms and Mechanisms. It policy controls the Security-management-DE embedded in a IMS functions (nodes) to collaboratively implement self-protection and self-defence behaviours for IMS network (considering IMS network domains between different players and in the network domains). It realizes the outer slow control loop that pertains to adaptive tuning of security enforcement behaviours in the IMS network. It policy controls the "mirror Security-Management-DEs" that may be available at the node levels.
IMS-unified GANA KP	Network	Fault-Management-DE	The GANA KP DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of End to end Fault Detection Mechanisms, Fault Isolation/Localization/Diagnosis Mechanisms and Fault Removal Mechanisms for the different IMS nodes of the IMS network. It realizes the outer slow control loop that pertains to adaptive tuning of fault-management behaviours in the IMS network. Its policy controls the "mirror Fault-Management-DEs" that may be available at the node levels.
IMS-unified GANA KP	Network	Mobility Management-DE	The GANA KP DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of Mobility Management Protocols (SIP mobility and IP-CAN Selections) and Mechanisms. Identify the mobility decisions policy used by Mobility Management DE in the nodes. It realizes the outer slow control loop that pertains to adaptive tuning of mobility management behaviours in the IMS network. Its policy-controls the "mirror Mobility Management-DEs" that may be available at the node levels.
IMS-unified GANA KP	Network	Routing Management-DE	(not applicable, but relay on IP-CAN as it, could optimize flow capacity, number of, link reliability, provides network-wide address planning, topology management. Its policy-controls the "mirror Routing Management-DEs" that may be available at the node levels.
IMS-unified GANA KP	Network	Resilience & Survivability-DE	The GANA KP DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of Proactive and Reactive Resilience Mechanisms, Survivability Strategies and Algorithms, Restoration and Protection Mechanisms for the network as a whole by policy controlling the "mirror Resilience & Survivability-DEs" as the node level. It realizes the outer slow control loop that pertains to adaptive tuning of resilience and survivability behaviours in the IMS network. Its policy-controls the "mirror Resilience & Survivability-DEs" that may be available at the node levels.

IMS Entity	GANA Level	DE type	Specific IMS functionality that should be autonomically (dynamically and adaptively) managed by the corresponding Decision Element (DE) software
IMS-unified GANA KP	Network	Applications & Service Management-DE	The GANA KP DE is responsible for orchestration and dynamic/adaptive (closed-loop) management and control of Services and Applications (while identifying the different chain of process to be used to deliver services and their constraints). It realizes the outer slow control loop that pertains to adaptive tuning of applications and service behaviours and performance in the IMS network. Its policy-controls the "mirror Applications & Service Management-DEs" that may be available at the node levels.

NOTE 4: Table 1 "A mapping of DEs from the Network-Level down to the GANA lowest layer/level Managed Entities (MEs)" in ETSI TS 103 195-2 [i.5] complements this table presented in this clause, as it also provides complementary details on mappings of DEs to Managed Entities (MEs) Types, and implementers should consider the table in ETSI TS 103 195-2 [i.5] as well when implementing specific DEs and control loops over their intended specific MEs.

NOTE 5: Implementers of DEs for autonomics in IMS should consider, apart from DE-to-ME mappings (1 ME to exactly 1 DE relationship), the Management Objects (MOs) of the specific MEs in IMS that may be available for the DE logics to be designed and use in adaptive management and control of their MEs. Such MOs of specific MEs may be defined in models like a MIB (Management Information Base) such as SNMP MIBs. There are many documents on IMS that specify Management Objects (MOs) for specific MEs and implementers of GANA KP Platforms need to also do a mapping of the MOs of specific MEs to their owner-DEs and to resolve the question of "Which GANA KP is responsible of dynamically setting (configuring) the MOs in the hosting NEs/NFs or Terminals.

NOTE 6: Clause 7.2 provides insights on Other Kinds of Data/Information that can be fed into GANA KP Platforms in Driving Autonomics for IMS Services.

NOTE 7: As discussed earlier in clause 4 and in ETSI TS 103 195-2 [i.5] and [i.26], there is a need for coordination of KP DEs in achieving global autonomics/AMC objectives. More details on this subject are covered in ETSI TS 103 195-2 [i.5] and ETSI 5G PoC White Paper No.2 [i.18].

NOTE 8: There is a lot of research work in literature on autonomics for IMS, and such research results can be exploited to implement DEs and autonomics algorithms recommended in the present document on GANA instantiation onto IMS networks and functions. Examples of research work on autonomics for IMS are [i.15], [i.23], [i.24] and [i.29].

6.6 IP Multimedia related Managed Entities (MEs) of the respective GANA Knowledge Plane Platforms that should be adaptively (re)-configured by KP DEs

The different functions below have been identified as functions that can be enhanced with advanced self-management functions (i.e. GANA DEs) and autonomics - control-loops driven management and control of resources, parameters and global behaviour by collaboration of DEs and KP Platforms that adaptively manage functions:

- BGCF: Breakout gateway Control function (in BBF architecture)
- MGCF: Media gateway Control Function (in BBF architecture)
- S-CSCF: Serving Call Session Control Function
- P-CSCF: Proxy Call Session Control Function
- I-CSCF: Interrogating Call Session Control Function
- SLF: Subscription Locator Function
- AS: Application Server

- HSS: Home Subscriber Service
- MRFC: Multimedia Resource control Function
- MRFP: Multimedia Resources Function Processor
- PCEF: Policy control enforcement Function
- PCRF: Policy Control Resource Function
- BCF: Border Control function
- UE: User Equipment
- UA: User Agent

7 Characterization of IMS Knowledge Plane (KP) Level DEs by illustrating examples of DEs' autonomic operations

7.1 Overview

The GANA Knowledge Plane should fulfil the combined role of Network Analytics Driven Service Orchestration and Network Analytics Driven Closed-Loop (Autonomic) Service Assurance and Security Assurance:

- Network Analytics Driven Service Orchestration should be performed by the Knowledge Plane DEs in response to network or resource capacity demands and resilience targets/objectives.
- Network Analytics Driven Closed-Loop (Autonomic) Service and Security Assurance should be performed by the Knowledge Plane DEs with the target of improving customer experience. Autonomic (Closed-Loop) Service Assurance involves the Knowledge Plane as an Analytics Platform equipped with engines (DEs) that collects and analyses data from various data sources such as traditional Service Assurance Platforms (e.g. Performance management systems), network service functions/nodes, SDN Controllers, etc., and detect any service degradations and SLA violations. The Analytics Platform then closes the loop by communicating monitor results to Orchestrators and triggering remediation and corrective operations via a combination of Service Orchestrators, SDN Controllers, and Service Functions/Nodes such as CPE, Access Network (AN), Border Network Gateway (BNG). The Knowledge Plane DEs should be able to communicate to a Service Orchestrator Results obtained from Monitoring a Service such as SLA violations and generate Recommendations (actionable insights) on how the problems can be solved (humans could make use of the generated Recommendations, e.g. making use of the Recommendations to perform the actions if the Knowledge Plane DEs are configured to operate in an "Open-Loop" Mode). At the same time in a "Closed-Loop" mode, the DEs should go further on their own accord to trigger operations on the Service Orchestrators (which include orchestrator types like the NFV Orchestrator) in a "Closed-Loop" (autonomic) service assurance goal based on what the DEs determine to trigger on an orchestrator or any other management and control system such as an SDN controller, so as to realize Self-Healing of the Service(s) - thanks to autonomics of the Knowledge Plane operations. While Service Assurance should now evolve towards "Closed-Loop" (Autonomic) Service Assurance, rather than the Service Assurance Function computing Recommendations as actionable insights and operate in a an open loop as discussed in White Paper Advanced Predictive Network Analytics [i.11], the GANA Knowledge Plane is meant to be an implementation of a Service Assurance Function that is *autonomic* in its operation, acting in a Closed-Loop fashion that drives Self-* behaviours (performed on the Managed Entities (MEs) of the network) such as **Self-Healing**, **Self-Organizing**, **Self-Optimizing**, **Self-Protection, Self-Repair,** etc., and exhibiting **Self-Awareness**.

- Offer insights that help the Operator to create and launch new types of services that could be offered to customers based on the Recommendations that the Analytics performed by DEs in the Knowledge Plane can produce with respect to the types of services (e.g. connectivity services) that can be provisioned over the capacity deduced to be available without compromising QoE (Quality of Experience) of end users currently served by the network. The Recommendations should be based on converged and aggregate analytics that are collectively correlated by the various DEs in the Knowledge Plane over historical usage trends of the E2E network capacity and other information such as performance trending data, etc.

Other Aspects for considerations are as follows:

1) The GANA Knowledge Plane (KP) is meant to provide the realm in which Decision-making Elements (DEs), as software, can be designed and implemented to perform and realize the following functions:

   - Network Analytics should be performed in the Knowledge Plane (KP) using various types of algorithms for reactive and predictive analytics, including Machine Learning (ML) and other types of cognitive algorithms such as Artificial Intelligence (AI) algorithms, in augmenting any network analytics performed at systems and platforms such as Data Collectors that feed generated knowledge into the Knowledge Plane. Some cognitive algorithms may also run on the ONIX Information Servers for further correlation of information stored in the ONIX, to maintain an updated view on knowledge pertaining to current state of the network and also knowledge pertaining to historical network state and decisions performed by DEs as historical traces. The analytics performed by KP DEs drive maintenance operations and as well as even marketing campaigns. Sources such as [i.12], [i.13] and many other sources in literature provide insights on data-sources for network analytics that can be performed on analytics platforms such as Data Collectors or at some management systems to generate some knowledge that can be supplied to the Knowledge Plane. The Knowledge Plane DEs can augment the knowledge by consolidating such knowledge and further performing aggregate analytics of information and knowledge from various input sources on a more global level. Cognitive algorithms discussed in [i.12] and many other sources on Knowledge Plane related topics, including results from research projects on autonomics and cognitive network management, and also some real implementations already achieved to some degree in the industry in the areas of Service Assurance and Big-Data Analytics Driven network management can also be applied in implementing the GANA Knowledge Plane (KP) Platform and its interfaces described in [i.14].

   - Complex Event Processing (CEP), Context awareness Engine, cognition techniques are employed by DEs in the Knowledge Plane, as described in [i.14].

   - Data collected in the network by probes in the NEs or probes specially instrumented to collect data such as traffic captured through means such as link tapping, should be made available to the Knowledge Plane DEs for the purpose of enabling their algorithms to perform optimization and diagnostics.

2) The ONIX Information Servers and services may be employed for realizing a Real-Time Inventory and retrieve information from different databases and share information with different Network domains.

The Autonomic Management and Control IMS Knowledge Plane (IMS_KP) stores and processes any information needed to self-manage IMS services offered by the IMS Functions (as GANA Nodes), and should exchange information with the other Knowledge Planes for the Fixed networks (Fixed Network_GANA KP), the Mobile networks (Mobile Network_GANA KP), the IP Multimedia networks Knowledge Plane (IPM_KP), the Circuit Switched Network knowledge plane (CS_KP); the Legacy Mobile Signalling network Knowledge Plane (LMS_KP).

The ONIX should be composed of the different legacy functional databases such as the PCRF, HSS, state database, and any other Information servers that can be federated together with these databases. Knowledge Plane DEs interface with the ONIX and use ONIX services, and they may also use the native interfaces supported by the individual information servers (databases) members of the ONIX.

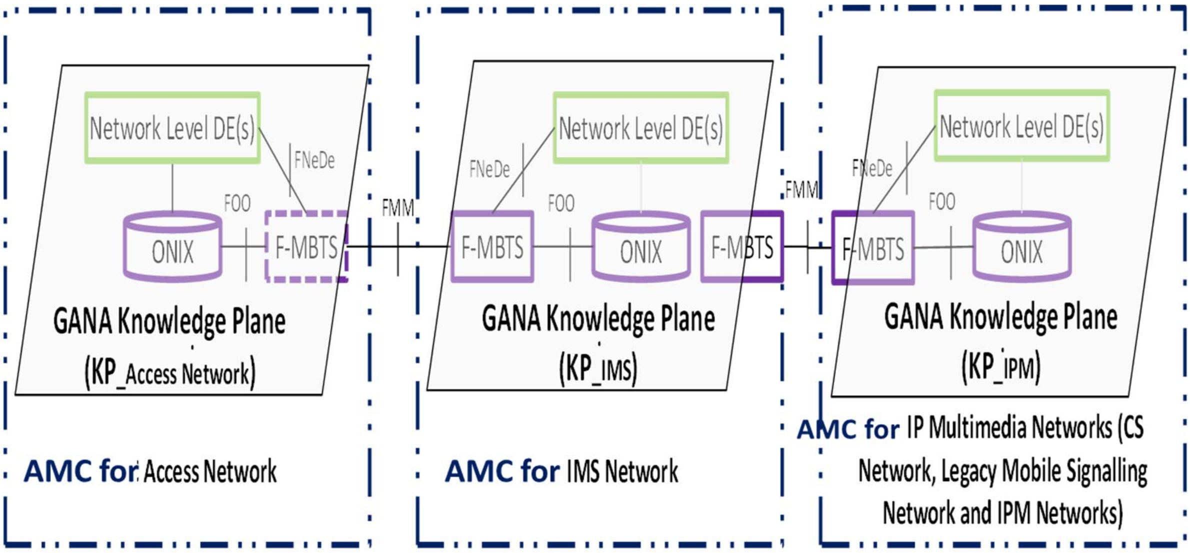

Figure 16: Federation of Knowledge Planes (KP) Platforms in the context of IMS

NOTE: Some examples of data and communications that may be required in KP-to-KP federations are provided in clause 7.2, and in NGMN 5G E2E Network Architecture White Paper [i.30] and in ETSI Technical Report on GANA instantiation onto BBF Architectures (ETSI TR 103 473 [i.9]) and in ETSI Technical Report on GANA instantiation onto 3GPP Backhaul and Core Network (ETSI TR 103 404 [i.38]).

7.2 Other Kinds of Data/Information that can be fed into GANA KP Platforms in Driving Autonomics for IMS Services

Apart from the various kinds of data/information that can be fed into GANA DEs for Autonomics in IMS described earlier in other clauses of the present document, there are other data/information that could be fed into KP Level DEs such as the KP level QoS-Management-DEs (or QoS & QoE-Management-DEs) such that such inputs can be considered by the DEs Algorithms in driving autonomics (self-adaption) for IMS Services delivery in such a way as to maximize Quality of Service and Quality of Experience. Examples of such input data/information include the following:

- Some Quality of Experience (QoE) data/information that can be provided as quality of experience scores for multimedia services consumed by end users: Such data/information can be provided to KP Platforms by users through some means. e.g. their end user terminal may be equipped with software agents that score the quality of the multimedia services or the users make the assessments and provide the data through some Generic User Interface on their end user terminals. There are some ideas that emerged in research that may be relevant to consider in regard to this aspect and also in regard to what could drive Autonomic QoS and QoE Management and even combined with Autonomic Mobility Management (refer to literature such as [i.33], [i.34], [i.35], [i.36] and [i.37].

- [i.27] presents the idea of Machine Learning (ML) based measurements for Call Stability Score (CSS) KPI data that can be measured by an On-Line Test System and be fed into GANA KP Platforms such as IMS KP, and network segments specific KP platforms such that the KP can compute and execute a set of actions meant to improve QoS and QoE for services delivered to the network users such as 5G enhanced Mobile Broadband (eMBB) slice users.

- Weather related data/information measured in real time or predicted.

- Context Information such as public gatherings events or recreational events, sport events; or mobility patterns and distribution patterns in users' intended demands for multi-media service consumptions.

- geographical information of the connected user within an access network should be shared between the IMS GANA KP, the AS Emergency center GANA KP and the type of Access network GANA KP. In order to provide appropriate configuration Information to the User Agent with the geolocalized emergency call center telephone number should be provided by the AS Emergency center GANA KP according to the Network location retrieved by the Access Network GANA KP. Or used to configure the UA SIP telephone number according to the network location and identity of the customer.

- Mobility context information such as the type of access network used by the user equipment should be shared between the AS GANA KP (AS-SCC) and the Core network GANA KP in order to improve the QoE with appropriate Codec which could be used according to the access network link quality (FTTH, xDSL, 2G, 3G, 4G, 5G).

NOTE: Information such as Weather patterns and Context Information can be published into the ONIX system and KP DEs dynamically subscribe to receive such information and real-time updates from ONIX servers (see more insights in ETSI TS 103 195-2 [i.5] and its annexes) in order to compute plans of actions and times to execute the actions.

8 Perspectives on Implications of 5G and Network Slicing on Autonomics/AMC in IMS

There are a lot of insights emerging in the industry and in 3GPP on the role of IMS in 5G, with the following as examples:

- 3GPP released 3GPP TR 23.794 [i.43] that covers "the potential enhancements to the IMS architecture to enable IMS Functional Entity (FE) to integrate with the 5GC network functions to enable IMS applications to directly leverage the features and capabilities of 5GC". There are also other studies and technical documents pointing to roles that IMS can play in 5G, such as 3GPP TR 23.700-10 [i.39], 3GPP TR 23.700-11 [i.40], 3GPP TR 23.700-12 [i.41], ETSI TS 123 228 [i.1] and ETSI TS 123 501 [i.42].

- 5G IMS Platforms are expected to support technologies such as: **Development and Operations (DevOps), Microservice-Based IMS Network Slicing,** in an environment that provides for closed-loop to enable to automate service design, development, deployment and OAM tasks (i.e. for closed-loop (autonomic) service assurance by way of GANA DEs autonomics in IMS automating the OAM tasks).

- 5G and Beyond Multimedia communications and services will no longer be only for human consumptions using end consumer devices (UE: User Equipment), but even in the case of Internet of things (IoT) and Machine to Machine (M2M) machines will communicate with each other using multimedia content in certain use cases and contexts, meaning IMS may play a role in such application areas.

Therefore, Autonomics in IMS plays an important role in the GANA-based Autonomic and Cognitive Management and Control of 5G Slices and E2E Orchestration, as GANA KP Platforms should collaborate in Slice (re)-creation and Assurance based on various situations and KPIs computed by the GANA KPs during the operation of the 5G network. In some deployment scenarios OSS/BSS, MANO, SDN Controllers, and E2E Service Orchestrators may be used in Slice Creation and Fulfillment, and then KPs takeover the Slice Service and Security Assurance by adaptively re-programming OSS/BSS, MANO, SDN Controllers or even causing the creation of backup slices that can be used to switchover some traffic flows in adapting to situations by fixing problems in Slices or switching over traffic to backup slices. In other GANA KP deployment scenarios that may not use OSS/BSS systems, the GANA KP Platforms may be the ones that directly trigger the creation and fulfilment of slices and take care of autonomic (closed-loop) assurance of Slices.

Each GANA KP performs autonomic operations in respect of the Functions of the Layer or Network segment it is responsible for in a standalone manner and/or in collaboration with other GANA KPs that provide it some data/information (e.g. KPIs) of relevance to the operations. Figure 17 illustrates how a 5G Network Slice creation and assurance requires GANA KPs to be involved in performing some operations. The GANA KP Platforms may be the ones that directly trigger the creation and fulfilment of slices and also take care of autonomic (closed-loop) assurance of Slices or that the Slice is created using other means first such as through OSS/BSS System and then the KPs take over the autonomic assurance and SLAs guarantee and maintenance for the Slice.

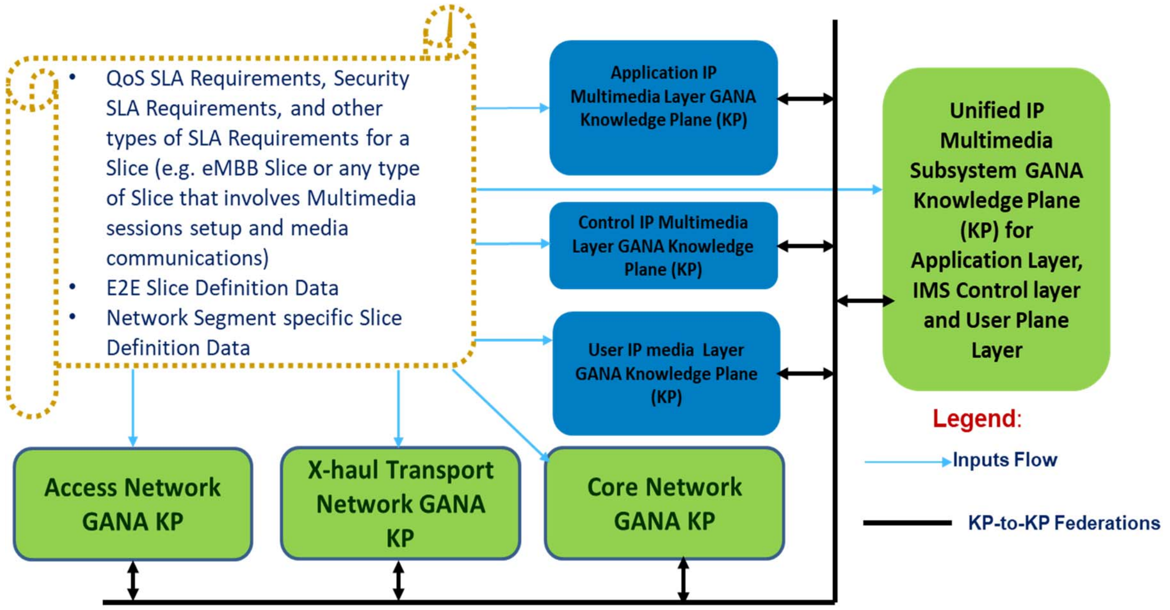

Figure 17: Illustration of the Implications of 5G Network Slicing on Autonomics in IMS and need for Federation of Knowledge Planes (KP) Platforms in the context of IMS

NOTE 1: Figure 17 considers some of the options discussed earlier in the present document regarding the GANA KP Platforms that can be considered for IMS environments.

To illustrate the impact of 5G network slicing on the GANA KP autonomics operations, the *KP level QoS Management DE (or KP level QoS and QoE Management-DE), KP level Monitoring-DE and KP level Security Management-DE* are used for the illustration (meaning that in Figure 17 above, it is assumed that these DEs are instantiated to run in the KP Platforms indicated):

1) The following inputs are supplied to the KPs depending on whether a specific KP may need the inputs in order to compute what it needs to configure for its Managed Entities (MEs) and compose its operations: *QoS SLA Requirements, Security SLA Requirements, and other types of SLA Requirements for a Slice (e.g. eMBB Slice or any type of Slice that involves Multimedia sessions setup and media communications), E2E Slice Definition Data, Network Segment specific Slice Definition Data.*

2) The *QoS Management-DEs (or QoS_and QoE Management-DEs) and Security Management-DE* of the various KPs use the Slice SLA related requirements inputs to derive configurations that need to be applied to their Managed Entities (MEs) in order to fulfil the SLAs, and collaboratively compute strategies for autonomic operations by the collaborating KPs to guarantee and maintain the SLA in the face of challenges and situations that may be detected or predicted in the network segments and management and control layers.

3) *GANA KP Monitoring DEs are their associated Monitoring Managed Entities (MEs) should use SLA definitions and their associated QoS Classes* in generating slice specific events and KPIs needed by the GANA KP Platforms for their E2E Autonomic (Closed-Loop) Service and Security Assurance across the various network segments and domains. The events and other monitoring data gathered concerning slice performance and other slice service impacting factors may need to be disseminated to the various GANA KPs as part of GANA KP-to-KP federations operations such that recipient GANA KPs use the information/data to dynamically compute and execute some actions that help guarantee and main Slice SLAs.

NOTE 2: Monitoring of Traffic needs to be based on on-demand monitoring principles and autonomic monitoring, and this subject is covered in ETSI 5G PoC White Paper No.3 [i.16] and materials from the Demo-3 of the PoC available at https://intwiki.etsi.org/index.php?title=Accepted_PoC_proposals.

In order to understand more the Implications of 5G and Network Slicing on Autonomics/AMC in IMS the following QoS Framework on Flow-Oriented (Flow-Level) Services & Telemetry Services delivered within a specific 5G Slice Type and varying in QoS Classes; Prioritization of Slices; and Definitions of QoS Classes and SLAs as inputs to Autonomic Service Assurance, gives more insights. The Framework is fully described in ETSI 5G PoC White Paper No.3 [i.16]. The following are snapshots of the concepts and ideas defined by the Framework in 5G PoC White Paper No.3 [i.16].

"

1) *QoS Framework for Services delivered within a specific 5G Slice Type:*

- ***Man-Machine Communication (MMC) Slice:*** *Network slice with real user involvement (Man-Machine Communication based slice). The best suited 3GPP standardized slice type for this mode is eMBB. Examples of Sub-Services (Flow-Oriented (e.g. IP Flow-Level) Services)) the Slice may carry:*
    - *Premium Video Services*
    - *Premium Audio Services*
    - *Regular Multimedia Services with User Profiling/QoS (Audio, Video)*
- ***Machine to Machine (M2M) Slice: Network Slice with Machine-to-Machine Operation Mode. The best suited 3GPP standardized slice type for this mode is mMTC.*** *Examples:*
    - *Automated Measurements of certain Metrics (e.g. KPIs) of relevance to M2M services delivered by the Slice*
    - *Statistics Collection & Monitoring Applications that are associated with the Slice and its performance on M2M services delivery*
- *Ac.Cl.: Access Class List (4G/5G)*

NOTE: This may also apply to other types of Slices like URLLC, etc.

2) *QoS Framework for Services delivered within a specific 5G Slice Type and Mappings to ETSI GANA*

- *Key Concepts:*
    - *Network Slice Width;*
    - *Slice Prioritization;*
    - *Services Grouping and allocation to Slices;*
    - *Access Class List (Ac.CL) mappings to Flow-Oriented (Flow-Level) Services (e.g. Customer IP Flow Services and Telemetry Services, Performance Test Services and specialized Application Flows) running within a particular Slice*
- *Mapping to the ETSI GANA Autonomics: The QoS-Management Decision Element (DE) of the GANA Knowledge Plane (KP) responsible for a particular network segment(domain) is the Autonomic Manager Component that is responsible for dynamic steering of resource (re)-allocation per slice, preemption and reprioritizing slices, resource adaptation per slice for maximal fairness, throughput, or SLA compliance enforcement, including Admission Control for QoS provisioning within a network segment as a domain, as well as autonomic operations required to guarantee QoS for Slices and flows they carry.*
- *SLA Definitions and their associated QoS Classes for specific E2E Slices should be fed as inputs to the Federated GANA Knowledge Planes for E2E Autonomic Service Assurance of the Slices (and the flow-level services they carry, e.g. IP Flows).*
- *The DEs in the GANA Knowledge Plane that need to receive SLA Definitions and associated QoS Classes as inputs to their operations:*
    - *GANA KP Monitoring_DE*
    - *GANA KP QoS_and_QoE Management_DE*

3) *QoS Framework for Services delivered within a specific 5G Slice Type (Continued)*

- *How to package services (e.g. Flow-Oriented (Flow-Level) Services & Telemetry Services) into Slices:*
    - *Services are grouped into categories whereby each service is delivered within the scope of one network slice and is allocated to a particular group.*
    - *Groups are of either MMC or M2M type and carry a priority label.*

- *Each network slice allocated to a service is dimensioned so that its resources match the service requirements (Bandwidth, Service Level Agreement (SLA)).*
- *As more services run on the network in slices, new services will contend for resources; and so a flexible QoS provisioning framework is required to be in place and is expected to handle resource management and orchestration of the services via admission control, resource reallocation.*
- *Possible plots are a service is denied access, slice widths are reassigned to fit a new service, a service is frozen to fit in a new slot, and queueing of a current lower priority service until resources are available."*

Figure 18 below, provides an Illustration of the concepts of Network Slice Width; Slice Prioritization; Services Grouping and allocation to Slices; and Access Class List (Ac.CL) mappings to Flow-Oriented (Flow-Level) Services (e.g. Customer IP Flow Services and Telemetry Services, Performance Test Services and specialized Application Flows) running within a particular Slice.

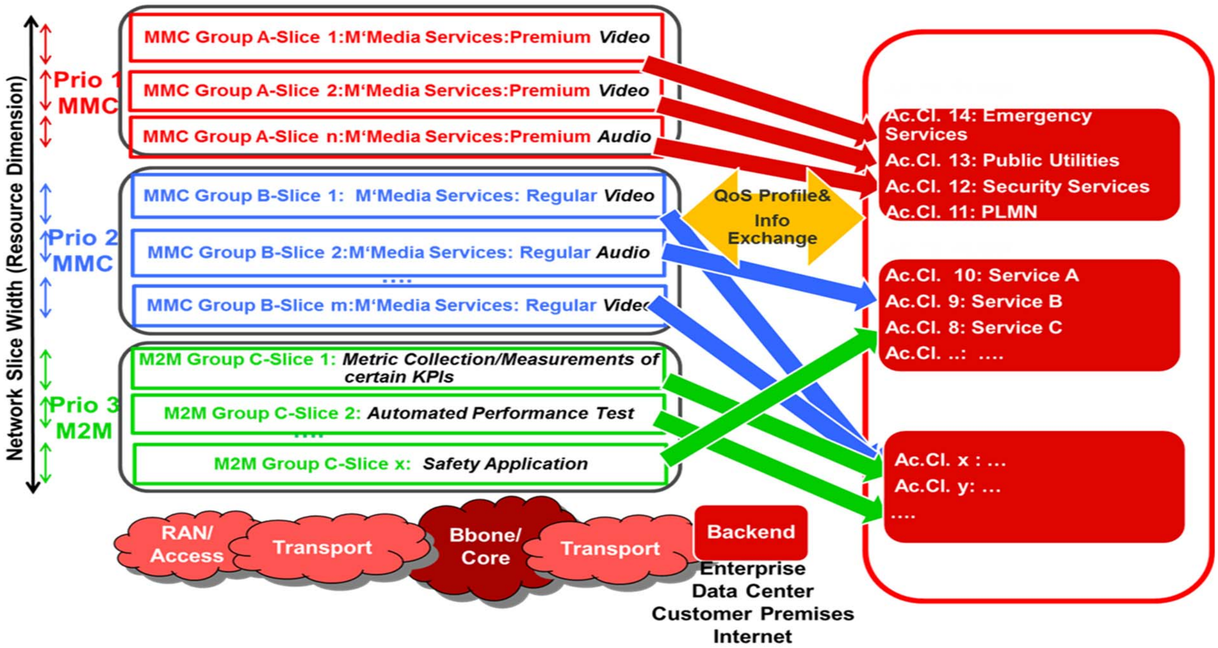

Figure 18: Illustration of the concepts of Network Slice Width; Slice Prioritization; Services Grouping and allocation to Slices; and Access Class List (Ac.CL) mappings to Flow-Oriented (Flow-Level) Services (e.g. Customer IP Flow Services and Telemetry Services, Performance Test Services and specialized Application Flows) running within a particular Slice

Table 2: Aspects that should be considered when assessing the viability and performance of a use case involving a mix of MMC Slice and M2M Slice

Use Case: Mixed MMC & M2M Scenario	Key Feature(s)	Example aspects for consideration in assessing such a Use Case
Users and M2M Entities share the network resources in the form of slices (E2E) up to a certain utilization factor. When/before a new service is initiated, a resource availability check is performed and then the service is launched within the allocate slice. Admission Control (AC) is a gateway/gatekeeper mechanism to allow a slice to be formed in the resource stack before a service is launched. Depending on the load and resource availability situation, the AC decision is made.	Admission Control	Service/Slice Creation Service/Slice Denial Service/Slice Reshaping before Admission **→ QoS Gatekeeper**
When a high network resource utilization factor is reached, the QoS mechanisms that handle the network slices should be able to reallocate resources among different slices for optimizing resource management. When a service from a high-priority group wants to join the network, the Resource (re)-Allocation (RA) mechanism negotiates with the AC mechanism	Dynamic Resource (Re)alloc.	**→ Flexible QoS**
A network slice can be frozen (e.g. a slice wholy occupied by a certain type of measurement application)	Slice Blocking/ Removal	**→ Slice Preemption, Slice/Service Queueing**

Annex A: Change History

Date	Version	Information about changes
October 2017	0.1.0	ETSI editing rules
September 2018	0.1.1	Add sections
July 2021	0.1.4	Final version that leveraged the results from the ETSI TC INT AFI 5G PoC (https://intwiki.etsi.org/index.php?title=Accepted_PoC_proposals)
April 2022	1.1.1	editHelp! review

History

Document history		
V1.1.1	May 2022	Publication