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5G NETWORK OPERATIONS

AI/ML BASED RECURSIVE AUTONOMIC OSS

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EXECUTIVE SUMMARY

5G is the 5th generation of mobile networks designed to meet the large growth in data and connectivity of today's highly mobile and fully connected society. 5G will bring new unique network and service capabilities. Firstly, it will ensure user experience continuity in challenging situations such as high mobility (e.g., in trains), very dense or sparsely populated areas, and journeys covered by heterogeneous technologies. In addition, 5G will be a key enabler for IoT by providing a platform to connect a massive number of sensors, rendering devices and actuators with stringent energy and transmission constraints. Furthermore, mission critical services requiring very high reliability, global coverage and very low latency will become natively supported by the 5G infrastructure.

5G networks use the concept of end-to-end network slicing, which enables the concurrent deployment of multiple end-to-end logical, self-contained and independent shared or partitioned networks on a common infrastructure platform, to achieve the performance and scalability requirements. Recursive network slicing, i.e., slices overlaid on top of other network slices, is also supported.

To manage such highly scalable and recursively sliced 5G networks and to maintain the customer QoE and SLAs in real time, the OSS systems managing the operations must be autonomous and self-driven. It should be AI/ML based and must support cognitive algorithms for automation of network operations.

Altran proposes a Reinforcement Learning based Recursive Autonomic OSS Solution for operating the 5G networks. The proposed solution is analogous to the concept of autonomic control systems and reinforcement learning present in the human body.

INTRODUCTION

The proliferation of connected objects and devices in the 5G networks will pave the way to a wide range of new services and associated business models enabling automation in various industry sectors and vertical markets (e.g., energy, e-health, smart city, connected cars, industrial manufacturing, etc.). In addition to more pervasive human centric applications, e.g., virtual and augmented reality augmentation, 4k video streaming, etc., 5G networks will support the communication needs of machine-to-machine and machine-to-human type applications. Autonomously communicating devices will create mobile traffic with significantly different characteristics than today's human-to-human traffic. The coexistence of human centric and machine type applications will impose very diverse functional and KPI/performance requirements that 5G networks will have to support.

There are three major categories of a use case for 5G:

- **Massive Machine Type Communications (mMTC)** – Enables the machine-to-machine (M2M) and Internet of Things (IoT) services that involve connecting billions of devices without human intervention at a scale not seen before

- **Ultra-Reliable Low Latency Communications (uRLLC)** – Mission critical including real time control of devices, industrial robotics, vehicle to vehicle communications and safety systems, autonomous driving and safer transport networks

- **Enhanced Mobile Broadband (eMBB)** – Provides significantly faster data speeds and higher capacity to keep the world connected. New applications will include fixed wireless internet access for homes, outdoor broadcast applications without the need for broadcast vans and greater connectivity for people on the move

The management, orchestration and operation of the 5G networks supporting the above category of services and associated performance requirements require unprecedented efficiency and automation levels. The OSS solutions for operating such networks need to be Intelligent to self-heal and auto-revive in real-time to address complex use cases and dynamic network behavior in real time.

This paper starts with an overview of the 5G network architecture, network slicing concept and key challenges in operating a 5G network. It then describes Altran's proposed reinforcement learning based recursive autonomic OSS solution for operating the 5G networks.

5G NETWORK ARCHITECTURE

5G Network architecture is highly service oriented in which services are provided via a common framework to network functions that are permitted to make use of these services. Modularity, reusability and self-containment of network functions are additional design considerations as per 3GPP specifications for a 5G network architecture.

Using SDN and NFV technologies, radio access (RAN), transport and core networks in 5G have been designed to be cloud oriented. Cloud orientation allows for better support for diversified 5G services and enables the key technologies of E2E network slicing.

NETWORK SLICING

Network slicing is an end-to-end concept covering all 5G network segments, including radio access, core, transport and edge networks. In a 5G network, it is defined as "a composition of adequately configured network functions, network applications, and the underlying cloud infrastructure (physical, virtual or even emulated resources, RAN resources, etc.), that are bundled together to meet the requirements of a specific use case, e.g., bandwidth, latency, processing, and resiliency, coupled with a business purpose."

Network slicing allows multiple logical networks to simultaneously run on top of a shared physical network infrastructure across multiple domains and technologies to create tenant or service specific networks. It aims for building dedicated logical networks that exhibit functional architectures customized to the respective telco services, e.g., eMBB, uRLLC, mMTC, etc. From a business point of view, a slice includes a combination of all the relevant network resources, network functions, service functions and enablers required to fulfill a specific business case or service, including OSS and BSS.

A pictorial representation of the Network Slice concept is given below:

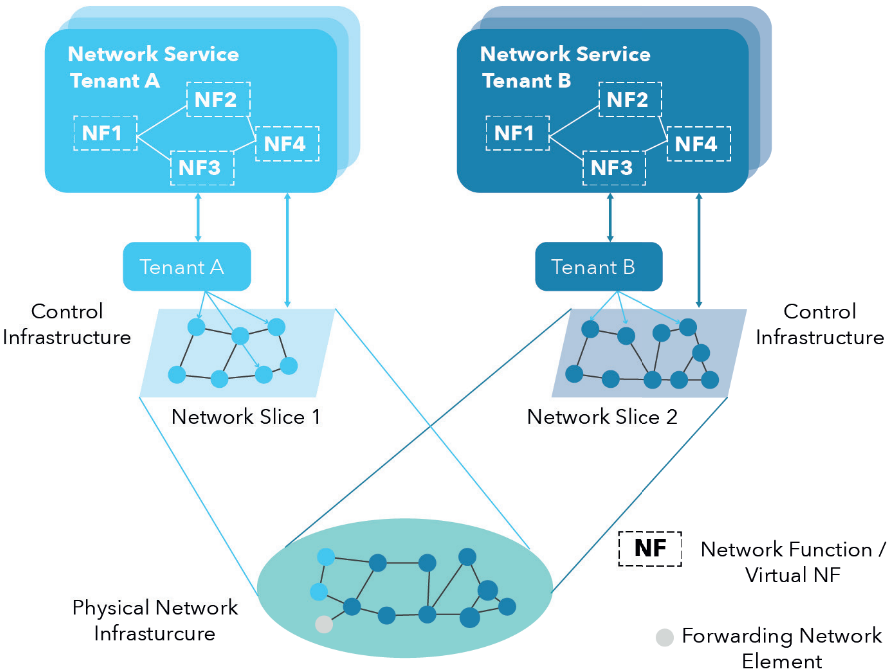
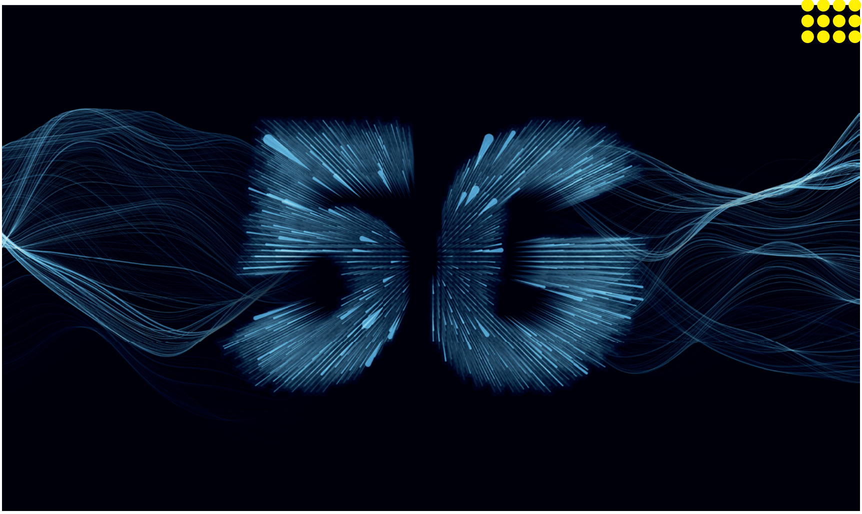


Figure 1: Network Slicing Concept



KEY CHALLENGES IN OPERATING A 5G NETWORK

5G networks are expected to support use cases such as enhanced mobile broadband (eMBB), ultra-reliable low latency communications (uRLLC) and massive machine type communications (mMTC) based on the characteristics such as ultra low latency, high data speeds and the ability to connect many IoT devices cost effectively. While the use cases and capabilities expected to be supported by 5G are compelling, operating such networks poses many different challenges. Some of these are described below:

- Management of the network slice instances recursively overlaid on top of other network slice instances
- Ensuring uninterrupted availability, rapid scalability, resilience and high levels of automation for the network slice resources monitoring and provisioning
- Adhering to the highly demanding SLAs associated with real time communication services
- Unified performance monitoring of a hybrid network composed of 3G/4G/5G physical, traditional, NFV and cloud infrastructure
- Monitoring network slice instances to ensure that virtual resources spun up for specific applications or customers will meet the required service levels and committed QoE levels
- Implementation of the automated cross domain and inter/intra slice correlation, root cause analysis and self-healing
- Accurate fault predictions and forecasting

- Automated self-driving processes and workflows for performance monitoring and fault resolution

- (Near) real time processing of massive amount of data generated from billions of devices

- Implementation of Advanced data analytics to generate intelligence that can infer, predict, forecast, fix and preempt network faults.

ALTRAN'S PROPOSED SOLUTION – REINFORCEMENT LEARNING BASED RECURSIVE AUTONOMIC OSS SYSTEMS

Altran proposes a reinforcement learning based recursive autonomic OSS system that is analogous to reinforcement learning and autonomic control in the human body. Below sections detail the human body autonomic functions and the proposed solution analogous to it.

Autonomic Control Systems & Reinforcement Learning in Human Body

Reinforcement learning is an area of machine learning inspired by behaviorist psychology. Humans use reflexes in some of their behaviors. In other words, how these reflexes manage their resources in adapting to unpredictable changes in the environment is defined by reinforcement learning.

The figure below shows how the reflex actions and reinforcement learning works in a human body. Reflex actions carried out by spinal cord occur automatically, but at the same time, as the reflex occurs, a signal is sent to the brain by a connecting interneuron (relay neuron) for further interpretation and additional reaction. When this happens, the stimulus is processed by the spinal cord as a reflex arc and a response is sent back to the periphery, through the motor neuron.

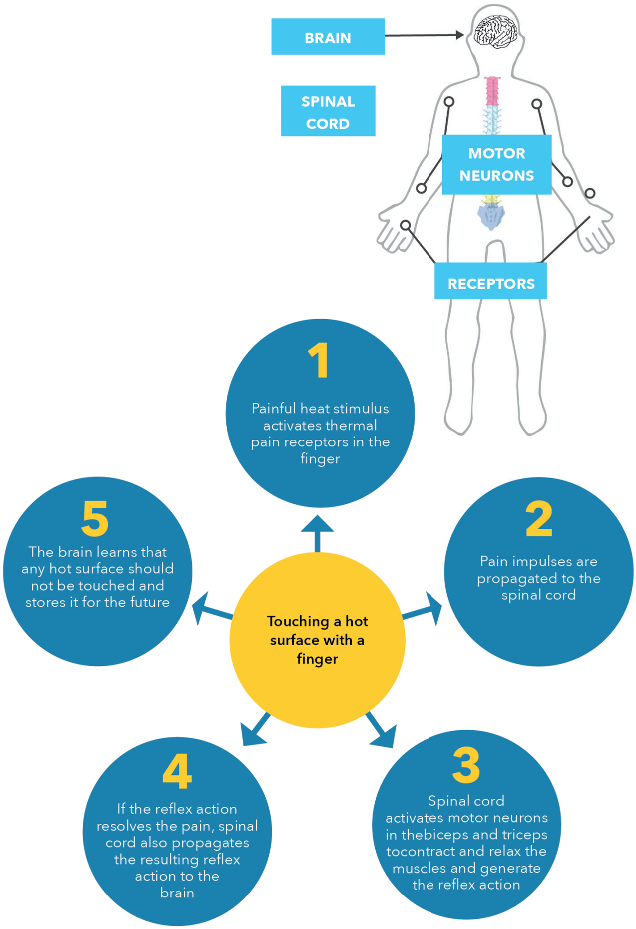


Figure 2: Reflex Actions and Reinforcement Learning in Humans

There are two control centers that define reinforcement learning – Central Autonomic Control System (CACS) and Local Autonomic Control System (LACS). These systems are inherent in the human body. The reflex arc is analogous to the LACS and the brain is analogous to the CACS. The reflex arc processes any signal that needs an immediate response. But at the same time, it also propagates the reflex action to the brain as a signal. The brain learns from this signal (reinforcement learning), processes it further based on signals received from other sensors and receptors, and applies this learning when the body goes near a hot surface next time.

Autonomic Control Systems & Reinforcement Learning in 5G Network Operations

The concept of "autonomic control systems" and "reinforcement learning" can be applied in network operations to achieve the dynamism and agility required for managing the 5G networks. The figure below shows a one to one mapping of each step taken by the human body (when a hot surface is touched with a finger) with the corresponding steps to be taken by the network when an event such as a spike in the data traffic is captured.

Figure 3: Reinforcement Learning in Network Operations

The captured event are propagated to the LACS, which functions as the reflex arc and takes immediate remedial actions. The event, remedial action and its result is propagated to the CACS which stores it in its knowledge plane.

Local Autonomic Control System (LACS)

LACS in network operations is implemented as a closed loop automation system driven by pre defined rules, policies and the knowledge cache. Offline and online mechanisms create the knowledge cache.

In the offline method, the knowledge/learning data is pre populated in the form of training data sets that can be used for making decisions. In the online method, the knowledge/learning data is pushed from the CACS on an ongoing basis.

Central Autonomic Control System (CACS)

CACS is implemented like the human brain, an intelligent system that can identify the various scenarios and patterns in network traffic, decide on the best possible action(s) to be taken, learn from the outcomes of the actions and update its knowledge plane with the learnings.

The CACS comprises of deep machine learning models based on neural networks. These models are applied to identify traffic patterns and reasoning to decide on the best possible action.

The CACS propagates all the learnings back to all the LACSs which are connected to it. This ensures that the local knowledge bases of all the LACSs are updated with this learning and they can apply this knowledge next time such an event occurs.

The figure below shows the working of the CACS at a high level.

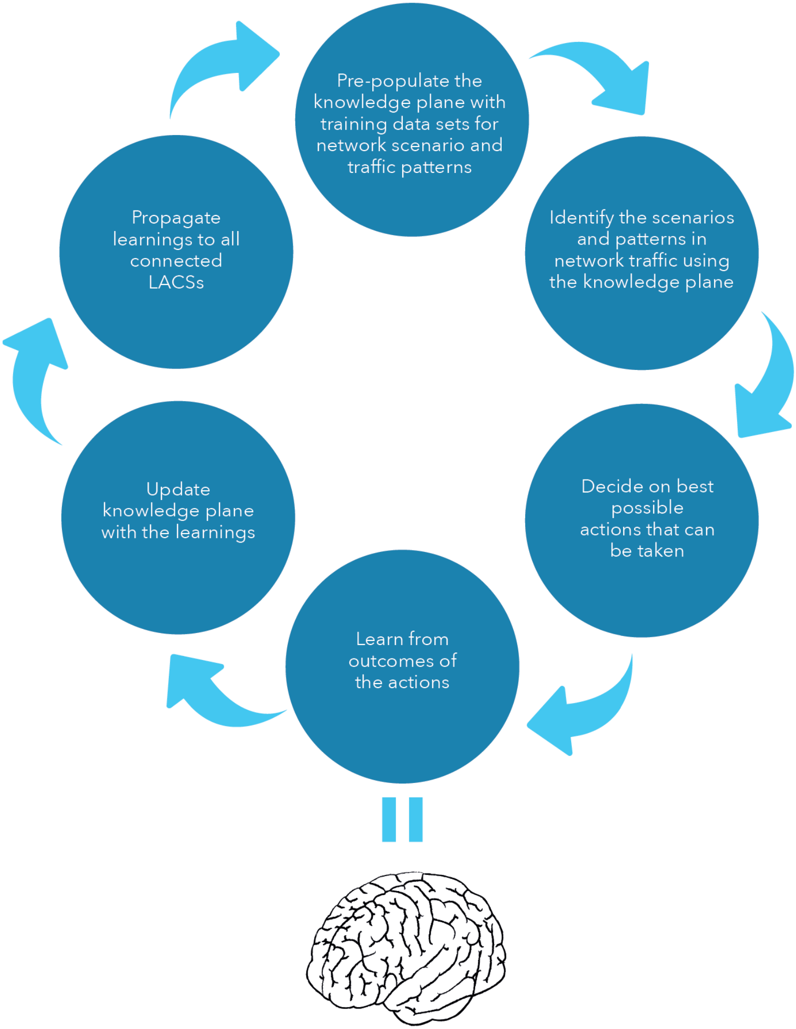


Figure 4: High Level Working of CACS

Autonomic Control Systems in the 5G OSS Architecture

In the OSS architecture for 5G, distributed OSS systems are implemented as autonomic control systems, as shown in the below figure.

Local Autonomic Control System (LACS)	=	Network Slice Manager - Local Autonomic OSS
Central Autonomic Control System(CACS)	=	Central Autonomic OSS

Figure 5: Autonomic Control Systems in OSS Architecture for 5G

The CACS is implemented as the central autonomic OSS, responsible for the overall management and orchestration of network slices and services over the network operator's 5G network.

The LACS is implemented as the local autonomic OSS, which acts as the network slice manager and is responsible for the lifecycle management and orchestration of network slices and services within each slice.

The overall OSS architecture for the 5G network operations is depicted below:

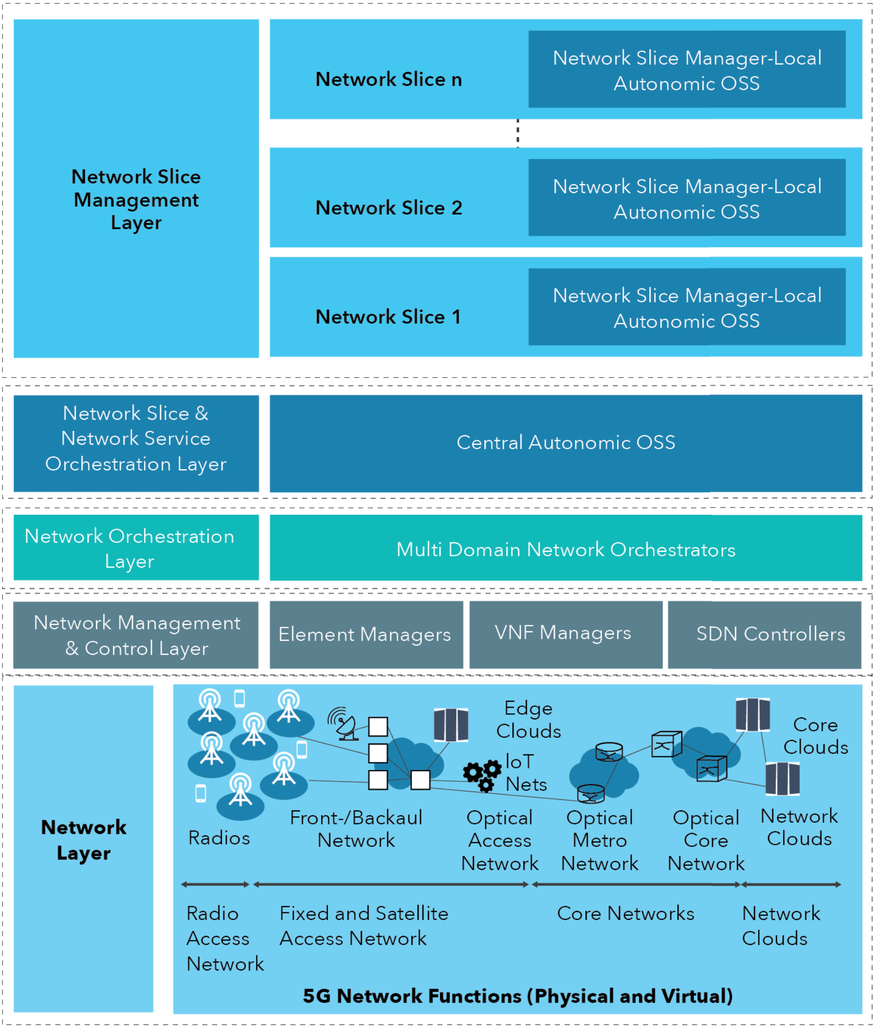


Figure 6: Overall OSS Architecture for 5G

The different layers in the architecture are detailed below:

- Network Layer: This layer hosts all the 5G network functions (physical & virtual) of the 5G network operator

- Network Management & Control Layer: All the element managers, VNF managers and network controllers are a part of this layer

- Network Orchestration Layer: Network resource orchestrators of different domains (access, core, transport, etc.) and multi domain network orchestrators are a part of this layer. These are responsible for interfacing with the element & VNF managers and SDN controllers to allocate and activate the network resources as required

- Network Slice & Network Service Orchestration Layer: This layer comprises of the central autonomic OSS system. It is responsible for the fulfillment and assurance of network slices and services provided by the 5G operator

- Network Slice Management Layer: A network slice can be overlaid on top of another network slice which can happen recursively. Whenever a new network slice is created and activated, a local autonomic OSS system is spawned by the parent (central/local) autonomic OSS for the resource management

  This layer comprises multiple local autonomic OSS systems responsible for the fulfillment and assurance of all recursively overlaid parent and child network slices.

The concept of recursive spawning of local autonomic OSS systems is detailed below.

Recursive OSS Architecture

The central autonomic OSS is the OSS system managing the fulfillment and assurance of 5G operator's network resources and the services & slices utilizing those resources. The local autonomic OSS is the OSS system managing the assurance of local network resources and any network slices recursively created using those resources.

The local autonomic OSS typically only captures the data related to the events and performance metrics of the network resources comprising the network slice of the tenant and would not intrude into the data related to the tenant's customers and product & service offerings.

A pictorial representation of the recursive OSS architecture is shown below:

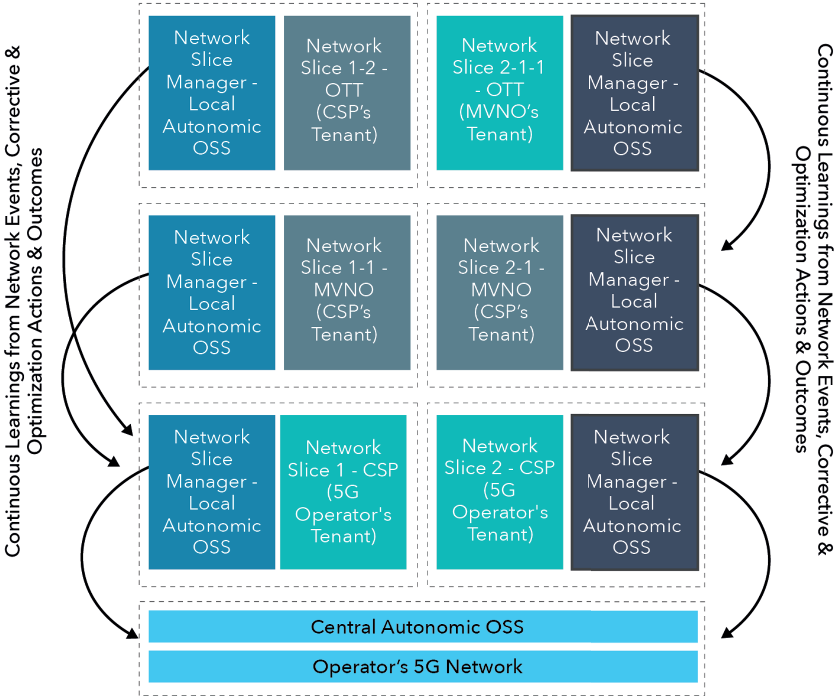


Figure 7: Recursive OSS Systems for 5G Network Operations

In the above figure, two network slices are created from the 5G network for two different CSP customer tenants. The recursive spawning of the local OSS systems for both the tenants in different scenarios are described below:

Network Slice 1: A local OSS system is spawned by the central OSS system when this slice is created. This local OSS system reports the fault and performance data of this slice and all its child slices to the central OSS system.

This CSP tenant further sells network slices to two of its customers – an MVNO and an OTT player. These are named as Network Slice 1.1 and Network Slice 1.2. Two local OSS systems are spawned by the local OSS system (of the CSP) when these slices are created. These local OSS systems report the fault and performance data of these two slices and all their child slices to their parent local OSS system.

Network Slice 2: A local OSS system is spawned by the central OSS system when this slice is created. This local OSS system reports the fault and performance data of this slice and all its child slices to the central OSS system.

This CSP tenant further sells a network slice to its MVNO customer. This is named as Network Slice 2.1. The MVNO further sells a network slice to its OTT customer. This is named as Network Slice 2.1.1.

Two local OSS systems are spawned by the local OSS systems (of the CSP and the MVNO) when these slices are created. These local OSS systems report the fault and performance data of these two slices and all their child slices to their parent local OSS systems.

The local OSS systems report the following data to their parent OSS (central/local) system:

- Faults/events generated by network resources and their corrective actions along with the corresponding results
- Performance metrics and KPIs
- Performance threshold breach faults/events and their corrective actions along with the corresponding results

All the above data is stored in the data lake within the central autonomic OSS system. The corrective actions are their results and are used for the continuous reinforced learning and the learnings are recursively propagated from the central OSS system to all the child OSS systems.

Central Autonomic OSS

Functional architecture of the Central Autonomic OSS is depicted below:

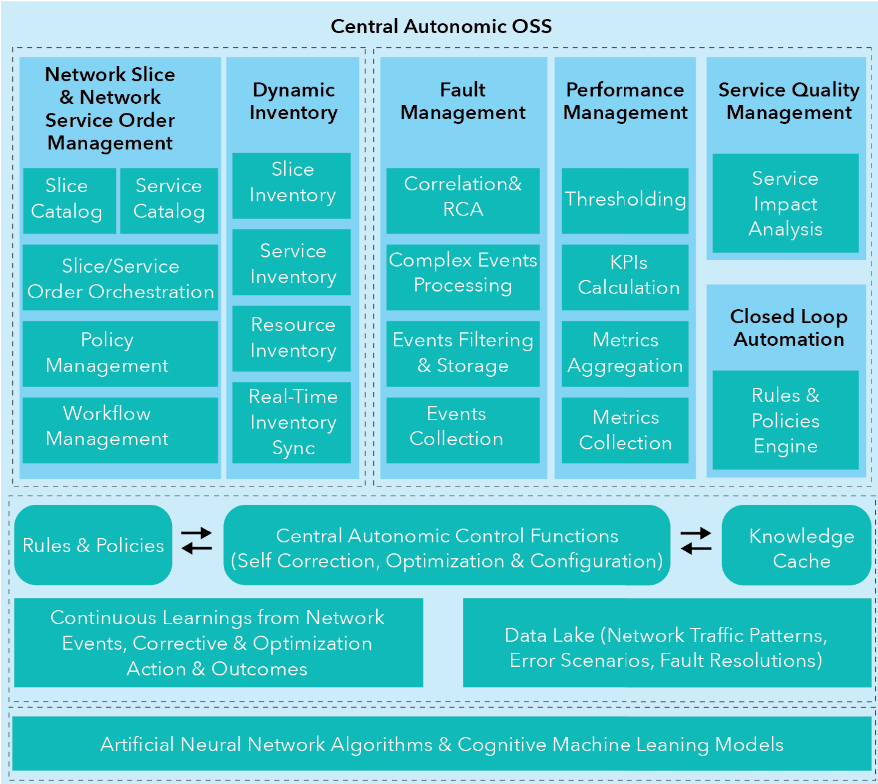


Figure 8: Functional Architecture – Central Autonomic OSS

The central autonomic OSS provides fulfillment and assurance functions for the network slices, services & resources in the 5G network. The different components are described below:

- Network Slice & Network Service Order Management: This component includes catalogs for the network slice and network service templates and provides the order orchestration and policy & workflow management functions for the instantiation of network slices and services

- Dynamic Inventory: This component stores the inventory of the slice and service instances, and their mappings with the network resources. It also includes a function for the real time synchronization of inventory data with the network

- Fault Management: This component provides the fault management functions such as event collection, filtering, processing and correlation

- Performance Management: This component provides performance management functions such as metrics collection, aggregation, KPI calculation, thresholding and reporting

- Service Quality Management: This component provides capabilities for service modeling, monitoring and service impact analysis

- Closed Loop Automation: This component provides capabilities for rules and policies defined to define the actions that can be taken against different fault conditions for self-healing

The Central Autonomic OSS System also provides the following functions:

- Rules based self-healing, optimization and configuration
- Reinforced continuous learnings based on corrective & optimization actions and their outcomes
- Data lake storing the massive amount of data for network traffic patterns, error scenarios and fault resolutions
- Deep learning models based on neural networks & cognitive algorithms for data analytics, self-healing, forecasting, network optimization and fault prediction and preemption

Network Slice Manager – Local Autonomic OSS

Functional architecture of the Local Autonomic OSS is depicted below:

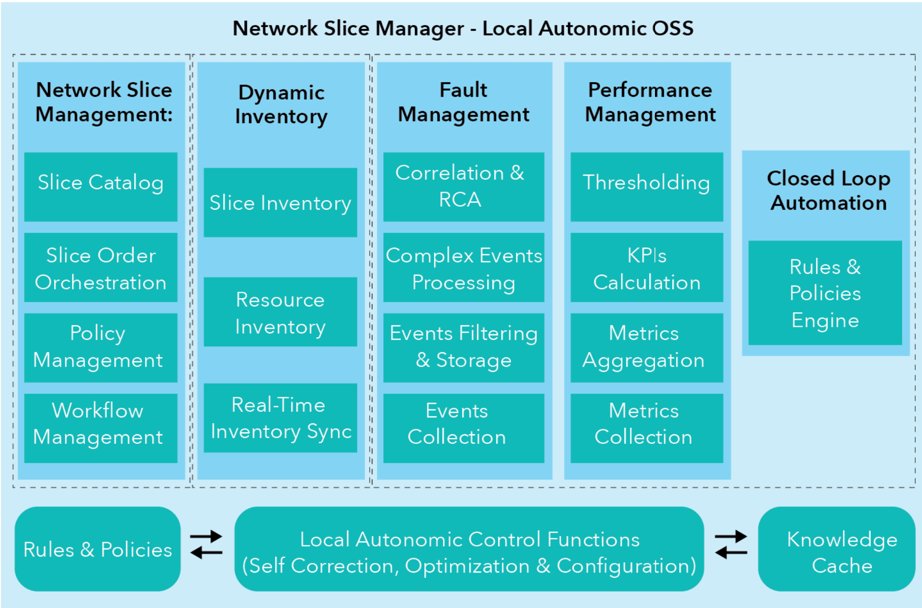


Figure 9: Functional Architecture – Local Autonomic OSS

The local autonomic OSS acts as the network slice manager and provides fulfillment and assurance functions for the network slices and resources. The different components are described below:

- **Network Slice Management:** This component includes a catalog for the network slice templates and provide the order orchestration and policy & workflow management functions for the instantiation of network slices

- **Dynamic Inventory:** This component stores the inventory of the network slice instances and their mappings with the network resources. It also includes a function for the real time synchronization of inventory data with the network

- **Fault Management:** This component provides the fault management functions such as event collection, filtering, processing and correlation

- **Performance Management:** This component provides performance management functions such as metrics collection, aggregation, KPI calculation, thresholding and reporting

- **Closed Loop Automation:** This component provides capabilities for rules and policies defined to define the actions that can be taken against different fault conditions for self-healing

Besides, it also provides local autonomic control functions for rules based self-healing, optimization and configuration.

CONCLUSION

5G Network Operations poses many different challenges such as real-time monitoring and management of recursively overlaid network slices, zero touch provisioning of network resources, adherence to highly demanding SLAs and real time processing of massive amounts of data generated from billions of devices.

A highly efficient, scalable and AI/ML enabled OSS system is required for operating the 5G networks.

Altran's proposed OSS solution uses the recursive model for reinforcement learning to achieve the required scalability and efficiency. The local OSS system manages all the individual network slices while the central OSS system performs the data analytics and machine learning work. Also, the proposed OSS solution includes a data lake to store the massive amount of network data that can be used for reinforcement learning and to train the deep machine learning models for network optimization and fault predictions.

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