Whitepaper of Catalyst Project

Autonomous Networks Hyperloops

– Enabling Self-X Digital Services for Smart-X Verticals

Objective(s): To implement and demonstrate the Autonomous Networks for Smart-X vertical industries (e.g. City, Entertainment, Manufacturing, Healthcare, Agriculture) by addressing the business requirements, architecture, capabilities and use cases through Simplified network, Agile IT & IoT solutions with Zero-X (Zero-wait, Zero-touch, Zero-trouble & Zero-friction) customer experience for Self-X (Self-Serving, Self-Fulfilling, Self-Assuring) capable digital services powered by autonomous domain, intent based interaction & closed loops. Smart City / Education sub-vertical is considered in this phase for demonstration.

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1. Introduction

1.1. The AN project background

Hyperloops, an Autonomous Networks value proof catalyst

Since years (just remember the first real smartphone 12 years ago) we are experimenting with digitalized versions of traditional business in many domains. The Covid19 period showed us that all of these digital assets are critical and that if well designed with lots of automated processes they avoid gaps in business and allow almost seamless functioning of many of our daily jobs. Imagine new "Disruptive" services that will be completely autonomous, designed for a zero-fault business through a new level of business & production system - using Autonomous Networks. The AN project was started last year, and this year we want to define & implement a real global ecosystem through a suite of domains and real-life use cases to validate AN Project. The catalyst will design, build, prototype different types of new value creating services for cities, entertainment, etc. vertical industries.

Considering the pandemic situation & global need for making education smarter, the first step in this journey is smart education within smart cities to facilitate management, deployment, operations, etc. The catalyst will focus on the top edge concepts and technologies: virtualization, edge compute, containers, AI, 5G etc. to develop quick demonstrable wins!

1.2. Why an implementation catalyst?

1. To move from project to reality, e**xploring operational versions** of the AN framework through real examples and architecture PoCs. From simple use case to a global vision exploring IoT network for smart-cities, Entertainment popup networks, Healthcare critical networks, Smart Agriculture, Smart Education etc.
2. **Validate the AN Project Vision:** we need to propose a real PDCA loop through a multi-year catalyst journey, that will cover multiple use case scenarios to define the precise, accurate & concrete framework and validate the hypothesis of the AN project
3. **Validate and foster the Project Architecture:** (i) Provide a very opinionated architecture with all the details on how to create such networks. (ii) Describe specific services and how they are delivered by single Autonomous Domains and then how some E2E services can be handled by multiple Autonomous Domains (Multi-Vendor, Cross-Domain). (iii) Details of Specific Components and API usage for 1 and 2
4. **Evangelize the TM Forum AN Framework:** Road-test key concepts of the framework (autonomous domain, Autonomous Networks levels, integration with different operational layers, all vertical, horizontal and cross layer loop.

2. Business perspectives

2.1. Domains of business to address

Following the true-life experience of massive digital services use during the Covid19 period, we can affirm that almost every single business domain is a good candidate to adopt such architecture of Autonomous Networks and services to avoid major impacts or outages. Our intention is to create a journey in different domains

- **Smart Cities:** Education, Waste, Traffic ...
- **Smart Manufacturing:** Autonomous Robot & Cobots
- **Smart Healthcare:** Robotic Surgery
- **Smart Automotive:** Autonomous Vehicle / AGV
- **Smart Grid:** Smart Meters, CH, Supply and Grid
- **Smart Entertainment:** SmartTV, AR/VR, Holograms

… to explore the technologies, the processes and the architectures to enable auto X frameworks based on business, functional intents. We will start with Smart City Education domain to obtain a first real autonomous platform mockup that will validate the theory of the AN project. We will then expand to other verticals to validate global prototypes with real case E2E closed loop.

2.2. Business stories

To create these frameworks (business architecture to technical / services architectures) this catalyst will develop a list of simple use cases that will demonstrate the feasibility and performance. We will create stories (as simple and easy as possible but effective to have short sprint realizations and real usage) using best advancement in simplified network, agile IT & intelligent IoT solutions powered by end-to-end Autonomous Networks to enable zero-x operations (zero-wait, zero-touch, zero-trouble & zero-friction). We will co-design the stories with domain related experts and city representatives to unlock new offerings and new potential revenue streams for all actors.

2.3. Business Impact

For DSPs (service providers), impact can be huge, providing one stop, real-time, on demand, automated services. The promise is to combine full lifecycle loops with business ambitions to obtain a seamless zero default service. For CSPs the impact is to develop new types of automated, autonomous platforms with real simplified architectures and on demand functions, to enable business and experience imagination drive the market.

2.4. Social Impact: Zero-X user experience

"Zero-X" (zero wait, zero touch, zero trouble) user experience enables simplicity for the users and offers service innovation based on fully autonomous business lifecycle of Self-X operating capability (self-serving, self-fulfilling and self-assuring).

2.5. Business Growth versus Operation efficiency

While "Operational efficiency" focuses on Telecom industry, "Business Growth" scopes vertical industries. Therefore, CSP needs to realize Autonomous ICT services with autonomous digital enabling services in addition to the challenges of cross-domain and hybrid network for innovative new services.

3. Ecosystems

Business, based on the technologies and processes delivered with Autonomous Networks, will typically be realized in the context of complex ecosystems. Few single service providers are today capable of delivering a wide-ranging solution for enterprise customers without relying on a fabric of delivery partners, and this will become even more prevalent in the future. Even consumer offerings are increasingly dominated by the value that the customer sees in the whole ecosystem, rather than the single product.

Customers are no longer happy for the CSP to run a week-long project to create an enterprise grade network solution, they want their private LTE or SD-WAN delivered the same day, with service levels in the famous five nines, and they want their changes to the networks acted on by the hour and minute based on their direct input – across all industries and sectors from financial services to manufacturing. The value creation (don't look at the value created for the CSP in a short sighted way but actual value provided to the customer!) is no longer driven by the ability to bring on expert teams of network engineers and many hands, but by the speed at which initial rollout as well as changes on the fly can be delivered. This demand from the customers can only be met by carriers that base their offerings on platforms that bring the relevant services in an ecosystem of specialized global and regional partners, that control the rollout with as much automation as possible, creating autonomously managed and maintained networks that absorb changed requirements in real-time.

> *Tailored, customer-specific solutions are likely to be increasingly important, challenging the classic telecoms business model in which mobile networks are built on a national scale by major CSPs on a one-size-fits-all basis to deliver a product defined centrally by CSP marketers and implemented in CSP BSS/OSS systems. Instead, solutions will be co-created and jointly delivered by service providers, their suppliers, and their specialist partners. This will require CSPs to transform their BSS/OSS to a digital platform that enables them to orchestrate these ecosystems.*
>
> (Omdia Research "INDUSTRIES AND ENTERPRISES ARE READY TO REAP THE BENEFITS OF 5G, 2020)

For such an orchestrated ecosystem of services and products working together, the number of partners and suppliers involved will greatly eclipse what we have seen in the communications industry so far. While CSPs are used to work with only two or three partners in a vertical or a horizontal service chain, the ecosystem needed and expected by their customers will be in the double digit numbers - this development has already started, but only few CSPs have accepted these facts. In such ecosystems, the efficiency and profitability of all business models relies heavily on the ability of the players to automate not only their own processes, but to evolve the operations of the whole ecosystem to achieve higher stages of autonomous management, in the service and resource layers as well as in the business interaction layer.

3.1. Business Model for AN models

It is not so much a question of specific business models that are needed for Autonomous Networks, but the other way round: the new business models that operators need to embrace to stay relevant in the future require new ways of managing the network and the business – the intent-driven interaction in the network as well as in the business domains.

To achieve this objective, operators need to transform their existing production, business and collaboration models in order to fully realize the potential of Autonomous Networks and the benefits they offer. Suggested new approaches to ecosystem and business models are as follows:

- ***Digital partner collaboration and ecosystem model****: all partners will collaborate to form partner ecosystems for offering on-demand, personalized and real-time services to the customers, which is different from traditional customer-provider-supplier model, AKA everything as a service.*

- ***Collaborative production model****: Leverage the best-suit solutions using best breed technologies through win-win benefit sharing collaboration in this new partner ecosystem.*
- ***Knowledge-as-a-service operations model****: to enable collaborative production, the operations knowledge should be shared and monetized through a common platform as an enabling service rather than cost reduction vehicle.*
  (from the TM Forum Autonomous Networks Whitepaper, R2, October 2020)

The change needed in the orchestration of products, services and business processes is related to basically all of the prevailing categories of business models in use today. The key elements of AN are as follows:

Table 1 Business Model Categorization

Business Model Category	Most relevant differentiation
business-to-consumer (B2C)	Level of AN achieved in User and Business Closed Loop
business-to-business (B2B)	Level of AN achieved in Service Closed Loop
Wholesale	Level of AN achieved in Resource Closed Loop
IoT/M2M	Level of AN achieved in Resource Closed Loop
business-to-business to X (B2B2X)	Level of AN achieved in User, Business and Service Closed Loop
Platform-as-a-Service,	Level of AN in achieved User, Business and Service Closed Loop
Anything-as-a-Service	Level of AN achieved in User, Business and Service Closed Loop

Starting already today, the business models in these basic categories will have to be even more diversified, (re-)inventing the play with new business models using ecosystems management and multi tenancy to collaborate, co-create, and sell new solutions with new technologies and partners (e.g. OTT, TV, 5G or IoT). The level of Autonomous Networks achieved by each participant, and together, will be a key factor in the profitability and success of the business models.

For this progress in achieving higher levels of Autonomous Networks (and Business), the operations need to be supported through Digital Business Platforms and Network Platforms. These platforms allow the automation and orchestration of the complex ordering processes that span multiple business units, multiple partner systems, and multiple geographies – exactly what is needed to evolve the overall engagement model towards the higher number of delivery partners referred to above.

3.2. Operators Business Models

Until now, telecoms industry business models have been all about selling high volume, repeatable and standardized network-based services largely to mass consumer markets. 5G, Edge and Cloud Computing on the other hand, opens many new possibilities in SMB and enterprise segments. While many of them are yet unclear, they will require CSPs to accelerate innovation, be bold and take risks and rapidly experiment with a growing number of services, solutions and new business models. It is clear that business models of telecom operators need to move beyond offering connectivity only: their role in the value chain could vary from providing essential tools and capabilities for ecosystem partners to build e.g. IoT solutions, to becoming an end-to-end IoT/IT/Cloud solution provider themselves.

3.3. Problem statements

The customers – in consumer and business/enterprise markets – are not the ones demanding that a CSP turns the management of his network and his business processes over to Autonomous capabilities. However, they demand products and services that will be increasingly hard to deliver in the requested swiftness and agility and at competitive prices.

Edge / 5G / Cloud business solutions are a technology play that solves problems centered on ultra-low latency, heavy bandwidth, & high capacity along with mobile edge computing capabilities configured to meet personalized connectivity needs. However, 5G solutions also involve a customer & services play that works by using the strengths of multiple partners. Coordinated drones, industrial production lines, operations video monitoring, low-latency gaming, remote healthcare procedures, Smart City scenarios, and augmented reality (AR)/virtual reality (VR) are just a few examples where partners play a substantial role in the 5G "solutions" designed to bring increased value to the customer experience. In this ecosystem, complexity abounds from:

- Implementing the right connectivity option for the type of business solution needed
- Provisioning and activating the solution, which can dynamically change at any time
- Pricing and charging for usage following a variety of new business models
- Monitoring solution quality and capability according to service-level agreements
- Tracking resource consumption for CSPs, their partners, their customers, and their customer's customers
- Flow of service-level revenue from customers to solution delivery participants & partner settlements

In an exemplary look at the challenges presented in the Smart Education Use Case, the following is the main starting point:

> **IDEAL:** Ideally customers are served by a seamless and one-touch AR/VR service ordering leading over to autonomous service fulfilment and activation.

REALITY: In reality, parts of the service need to be ordered from various players and later assembled. No end-to-end overview of expected delivery times exists, billing is achieved through invoice-stapling at best, and in case of later service problems a long search for responsible parties and contact points ensues.

CONSEQUENCES:

- CPQ is near impossible, discussing opportunities for the service with prospective clients takes weeks and months and are unlikely to close successfully.
- It is near impossible to determine the completion date of the whole offer across all the differently sourced components.
- The offer is not even available on the market yet, as the whole idea is still stuck in the build phase, and not even agreements between the participating service providers are fully locked in yet.

PROPOSAL: Have an end-to-end flow of orders, fulfilment, billing and assurance with minimal interruption and wait times due to manual intervention and handovers. Orchestrate the flow of interaction with closed loop control at the resource, service and product levels.

4. Smart Society as a first Use Case

The diagram below depicts the key industry specific use cases which Autonomous Networks powered by 5G & IoT promises to deliver. Use cases across these Smart-x verticals are weighted and Smart City is selected as the vertical of focus for initial validations of AN framework & Proof of Concepts realization. Within Smart city sub-verticals like Smart Energy, Smart Tourism, Smart Mobility, Smart Waste Management, Smart Environment, Smart Infrastructure & Smart Education use cases were evaluated to select the candidate for Proof of Concept. Smart Education is commercially expected to achieve a double digit CAGR for the next 5+ years and during pandemic like scenario, the lack of it has resulted in billions of kids deprived of learning.

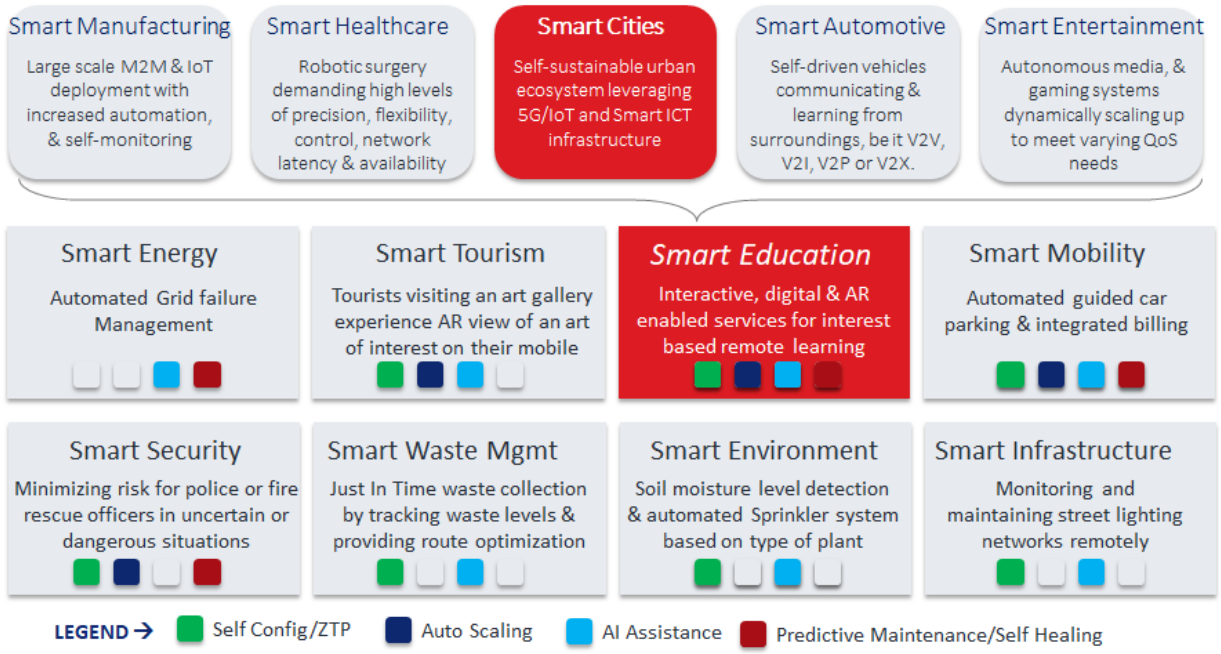

Figure 1 Smart-X to Smart City to Smart Education Use case selection

5. Technologies

5.1. **Simplified architecture**

The overlay/mixture of legacy networks e.g. DSL, 2G with modern networks e.g. GPON, 4G/5G, leads to the complexity of network architecture, operations and maintenance; and the deployment of emerging technologies e.g. virtualization, may incur significant effort on integration and operations if not designed and operated properly; diversity, dynamics and customization of application services e.g. IoT, add another dimension of complicating the usage of networks to meet different users need.

Simplified networks aim to enable the simplicity of network architecture (less layers, less hops) with digital capabilities (real time monitoring, analytics), normalized E2E protocols, minimized integration (less interfaces, closed loop execution) through cutting edge technologies e.g. AI enabled automation, big data analytics, edge and cloud computing etc., which is the underlying network infrastructure to enable the Autonomous Networks and corresponding services and operations. In particular to the smart education use case, it can improve the customer experience and service quality of the conversation/video/AR/VR with lower latency, faster processing time, and less cost and complexity of the integration of the 5G, IP/Optical transport with edge and IoT solutions.

5.2. Edge, Container, Virtualization

Virtualization empowers the disaggregation of the hardware to the software. Server virtualization was extended to the datacenter creating the concept of clouds. Virtualization optimizes resources by enabling users to run multiple virtual machines (VM)or virtual network functions (VNF) on a single physical server. However, each VM or VNF requires its own underlying OS and resources (CPU memory disk) while container technology enables the deployment of multiple applications using the same operating system on a single virtual machine or server making them cloud native.

Powered by virtualization and containerization, the industry is going through a digital transformation which requires agility (flexibility/adaptability) forcing SP and enterprises to design networks around the applications and operational models. The need for a dynamic, application-driven environment is particularly significant at the edge of the network which is fragmented and static. Virtualization technology makes it easier to deploy and run a wider range of applications and network functions on the edge computing nodes. Because this new architecture embraces a software-centric approach, it promotes more automation and service versatility. A prime example would be 5G use cases that target enterprise and industry vertical markets. Edge computing or Multi-access Edge Computing (MEC), is a crucial part of the 5G platform.

5.3. Automated to Autonomous

Automated and Autonomous Networks sound similar. However, the gap between an automated network and an Autonomous Networks is gigantic. Today networks automation is still limited to automating manual changes using configuration change management software. This one-off activity is triggered by experts and silos still exist between service provisioning and service assurance or between service fulfillment and device configuration.

To be considered autonomous, a network must operate with minimal to no human interventions. Configuration, monitoring, and close loop assurance activities should then be performed independently and automatically. To achieve such self-provisioning, self-diagnosing, and self-healing, AI technologies have to be applied and combined with network orchestration and automation solutions. AI-Ops is a first step towards Autonomous Networks, but AI alone is not enough and both the networks and the automation and orchestration solutions must evolve to allow Autonomous Networking. The infrastructure elements must be programmable so automation platforms can integrate them and wrap the whole infrastructure into a single API layer.

This software-driven infrastructure will allow automated networks to transform into Autonomous Networks. In the specific context of Smart Education Autonomous Networks, dynamically controlling the deployment of the application will offer students a seamless user experience allowing them to attend classes wherever they are and whatever the quality of the connectivity.

5.4. AI and Insights Analytics

Artificial Intelligence technologies is one of key enablers to Autonomous Networks, especially evolving from rule-based automation to self-operating intelligent system. However, due to the maturity and restriction of AI technologies, there is currently no panacea of AI algorithms and models to provide a universal solution for various use case scenarios and applications. The best practice is to combine multiple AI technologies e.g. machine learning, deep learning, knowledge graph and even traditional policy based expert system to achieve the best business value and customer experience.

Moreover, it is well known that it requires the data analytics technologies (sometime it is called big data) to monitor, collect and analyze the significant amount of corresponding data to train the AI model fitting in with specific use case scenarios; in addition, data analytics is also essential to provide the insights in the decision making process in conjunction with AI models. The smart education will benefit from the AI and insights analysis, for example, analyzing the video/AR/VR service quality, monitoring and deciding the root causes of failure to instruct self-healing closed loop.

5.5. 5G

The advent of 5G is pushing CSPs to rethink their business models and come up with newer design & deployment strategies, to cater to vertical specific enterprise use cases being promised by the capabilities of 5G and IoT ecosystem. 5G adds the capacity and latency to support a wider range of use cases, device types and network architectures (edge, virtualization, network slicing, SD/NFV, SD-WAN, AI/ML), but comes with increased network complexities and management issues and needs radically newer way of e2e architecture, control and management – “Autonomous Networks”.

XR (AR/VR/MR) applications have always been pushing connectivity limits because of the magnitude of complex features and functionalities like Tracking (Eye/Gesture) & Recording, Inertial, haptic and health sensors. This will be highly reliant on ultra-superior and ubiquitous connectivity, specially while moving at high speeds, to bring that premium user experience. XR applications will require 5G capabilities such as high capacity, increased throughput (multi-Gbps) per user and ultra-low latency (~1-5 ms) for tactile, 6DoF or a uniform immersive experience even at cell edge levels. 5G Ultra-low latency capability will be highly critical to ensure users don't experience motion sickness, disorientation or nausea, by improving the overall Motion-2-Photon (MTP) latency.

6. Architecture

Today's complex enterprise or city-wide networks demands a real-time, on-demand, dynamic and always-on automated and transparent flow of information, processing and storage across domains, multi-vendor infrastructure, physical, virtual or cloud resources for seamless service ordering, provisioning, fulfilment, activation, billing and assurance for enhanced customer experience and operational efficiency. This requires an e2e unified, integrated, automated and well-orchestrated network ecosystem which intelligently handles Business Automation, Service Automation and Resource Automation and mapping of Business resources to Services resources to network resources for e2e fault, configuration, accounting, performance and security management and control.

6.1. From Business Ecosystem to Business Architecture

Modern networks will be fully autonomous which mean the network will be self-sustainable and will carry out all complex functions on its own with minimal human intervention. Intent-based network management is one of the key drivers for building Autonomous networks. The Intent will represent the User/Operators objectives & business outcomes expected from the network, while the Autonomous nature of the network will bring "self-x" capabilities like self-serving, self-fulfilling, self-optimizing, self-assuring and self-healing along with closed-loop operations to fulfil the Intent.

Autonomous networks will abstract users/operators from the hassles and nitty-gritty of defining the appropriate network behavior; will provision required configurations or policies on each of the network devices finally to activate them. It will take this role to self-decide the future course of action in order to meet user/operators Intent while allowing them complete focus on defining their business outcomes. It dynamically adapts to the changes, reconfigures and optimizes resources using advance orchestration techniques across the physical and virtual domains network wide, assurance then provides the feedback though AI/ML confirming the desired outcome along with recommending continuous improvement. This concept requires a paradigm shift from current network or policy driven approach to a more business centric and intent driven approach across telco's functional layers – Channel, Customer, BSS, OSS and network - and equally supplemented by closed loop operations across these layers. Below functional architectural representation captures and marries the 2 aspects of Intent and Autonomous nature, which will be the driving forces for next generation of "Self-x" networks and services.

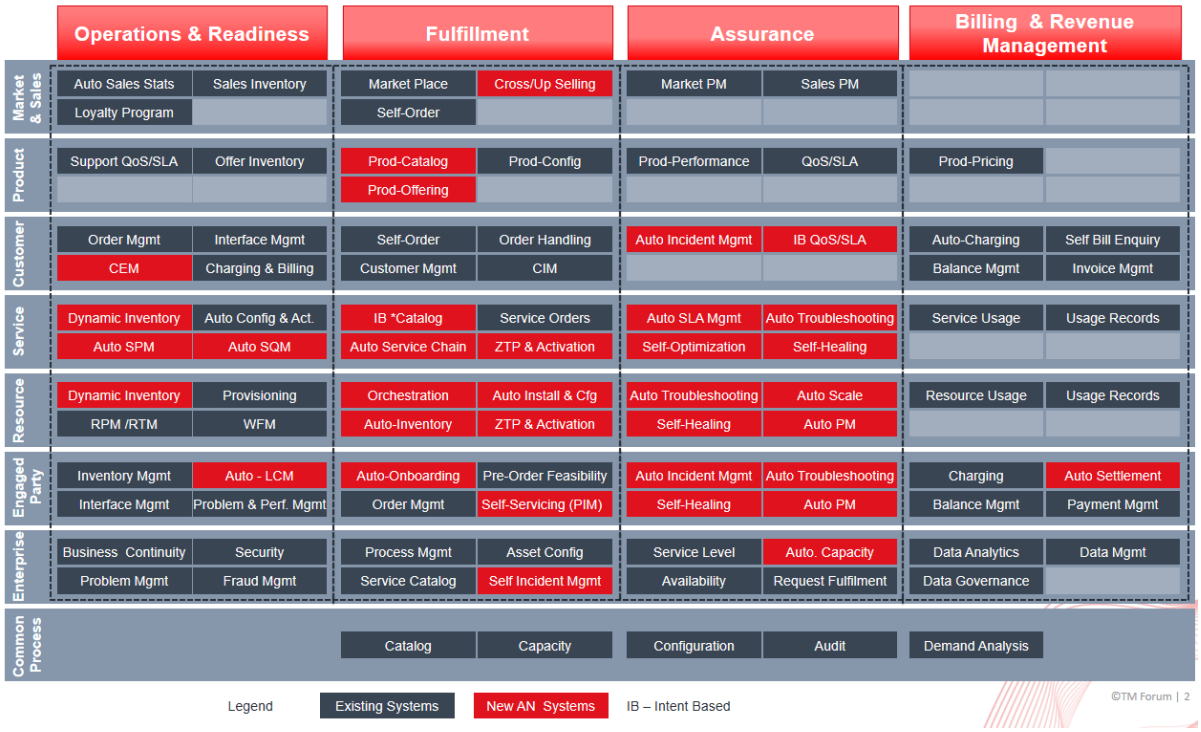

Figure 2 AN Business Process Framework

6.2. From Business Architecture to Technical Architecture

Per the business requirements and architecture defined in section 8.1, the key elements of AN technical architecture are the closed loops from business to service and resource operations through intent based simplified interaction, which can support various self-x operating processes (self-serving, self-fulfilling and self-assuring etc.) as defined in TMF document IG1218 [x].

The key elements of AN are as follows:

Table 2 AN key principles

Capabilities	Descriptions
Closed-loop	Define intelligent automation of full lifecycle of user/business/service/ resource operations with Self-X capabilities (e.g. self-ordering, self-healing, self-governing etc.) for Smart-Education applications
Autonomous domain	Explore the AD operations of key instances (e.g. 5G, Edge, Cloud) for various AN services (Autonomous ICT service/Digital enabling service)
Intent driven interaction	Implement business/service/resource intent mechanisms and interfaces for various applications (business/management/network) of Smart Education

6.3. Targeted Architecture

As defined in TMF document IG1218, the AN framework consists of 3 layers and 4 closed loops.

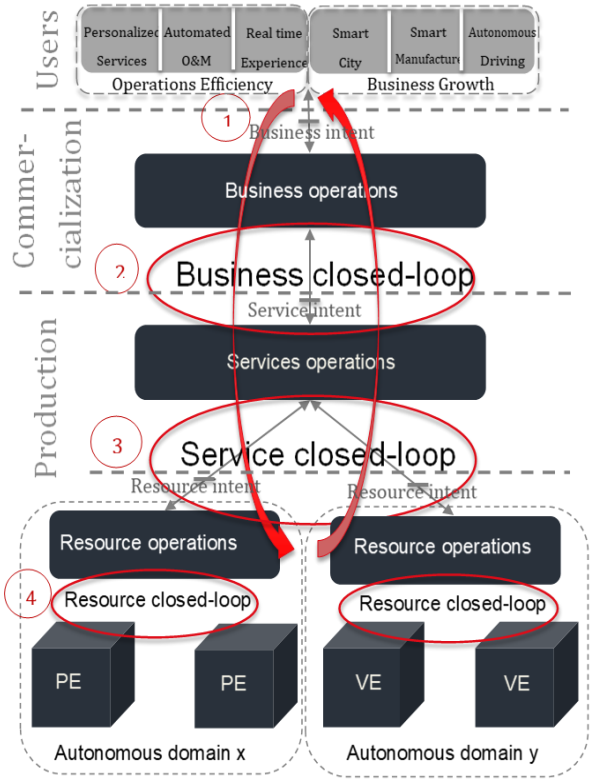

Figure 3 Autonomous Networks Framework

6.4. High Level Solution Architecture

The section describes a full life cycle of Autonomous Networks solutions and its requirements for dynamic business processes and models by leveraging cutting edge technologies like 5G, edge, AI, and virtualization. The project aims to implement, verify and illustrates the key capabilities of Self-X (e.g. self-ordering, self-fulfilling and self-serving) in a full lifecycle of user/business/service/resource closed loops of Autonomous Networks solutions. It is based on business intent to resource intent interaction, which is a requirement for dynamic business processes and models. We intend to demonstrate in our PoC how to wrap the infrastructure into a single API layer in order to enable zero touch provisioning and Self-x Operations.

The high-level solution architecture is illustrated in figure xx, which provides the key capabilities of Business Operations (BO), Service Operations (SO) and Resource Operations (RO) across three autonomous domains:

- Autonomous domain 1 (AD1) – Device. This AD supports different types of devices (e.g. IoT, AR/VR, AP/STB/mobile)
- Autonomous domain 2 (AD2) – Edge/access network. This AD supports the RO with real time processing and localization required for agents of connectivity, resource control, orchestration, data analytics and applications
- Autonomous domain 3 (AD3) – Cloud. This AD supports BO and SO for management and control, Intelligence & governance, as well as applications.

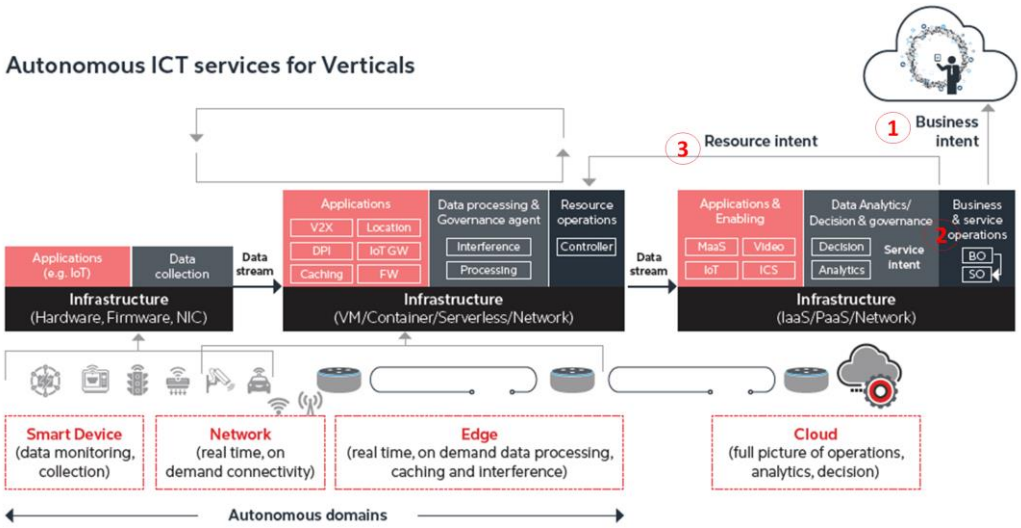

Figure 4 High-level solution architecture of Autonomous Networks

The interacting closed loops to ensure full end-to-end lifecycle operation and management, as follows:

1. Business Closed Loop:

a) **Business Request**: the user described their "Business Intent" (application attributes, SLA and key characteristics of AN services) to the “Business Operations (BO)” system in AD3 that requests AN services (e.g. xxx) for smart education.

b) **Business Fulfillment**: the BO translates the business intent into Service Intention (e.g., connectivity, availability, security, and quality of experience) and send as Service Intent requests.

c) **Business Close Loop lifecycle management**: The BO continuously guarantees that the Business intent is delivered and takes care of changes, if allowed, down to the termination.

2. Service Closed Loop:

a) **Service Request**: the SO in AD3 translates the Service Intent into Resource Intent (Resource (bandwidth, computing/storage) and QoS (latency, jitter, packet loss)) according to the requirements of each RO.

b) **Service Fulfillment**: the SO will interact and instruct “Resource Operation (RO)” in AD2 to deploy all required applications and orchestrate, manage, and monitor their resources.

c) **Service Close Loop lifecycle management**: The SO continuously guarantees that the Service intent is delivered end to end by the different RO and takes care of the service changes, if allowed, down to service termination.

3. Resource Closed Loop:

a) **Resource Request/fulfillment**: The RO of AD2 manages its resources to meet the needs of each service.

b) **Resource Fulfillment**: The AD2 also transfers and processes applicable data flow in the edge node in real time.

c) **Resource Close Loop lifecycle management**: Each RO continuously guarantees that the Resource intents are delivered by each AD and takes care of automatic reconfiguration of the network and IT resources (self-healing, self-optimizing) down to the releasing of the resources.

4. User closed loop with assurance:

a) Supported through streamlining the above 3 closed loops, for both service delivery but for service assurance.

b) Each Autonomous Domain monitors abnormal events (e.g., performance and fault events, or security attacks), and alerts other affected Autonomous Domains. Each affected Autonomous Domain collaborates to figure out the solution, and informs the BO and SO in AD3 when the solution is implemented and the problem is resolved. The SO may be involved in managing and orchestrating cross-autonomous domain events in real time.

c) **User Closed Loop Lifecycle management:** The BO, SO and RO are also in charge of monitoring the activity of the close loops (evaluation of the results of execution)

The mapping of Autonomous Networks Levels:

- **Level 2:** one or multiple Self-X capabilities supported in one of the steps of one lifecycle of business, service or resource closed loops e.g. self-ordering, self-organizing or self-healing
- **Level 3:** one or multiple Self-X capabilities supported in one or multiple full lifecycle of business, service or resource closed loops e.g. self-serving, self-fulfilling or self-assuring if applicable
- **Level 4:** All Self-X capabilities supported in one or multiple full lifecycle of business, service or resource closed loops e.g. self-serving, self-fulfilling or self-assuring if applicable
- **Level 5:** all Self-X capabilities supported in the full lifecycle of all closed loops

6.5. High Level Technical Architecture

AN Technical Solution architecture to achieve AN framework with Self-X capabilities is as depicted below

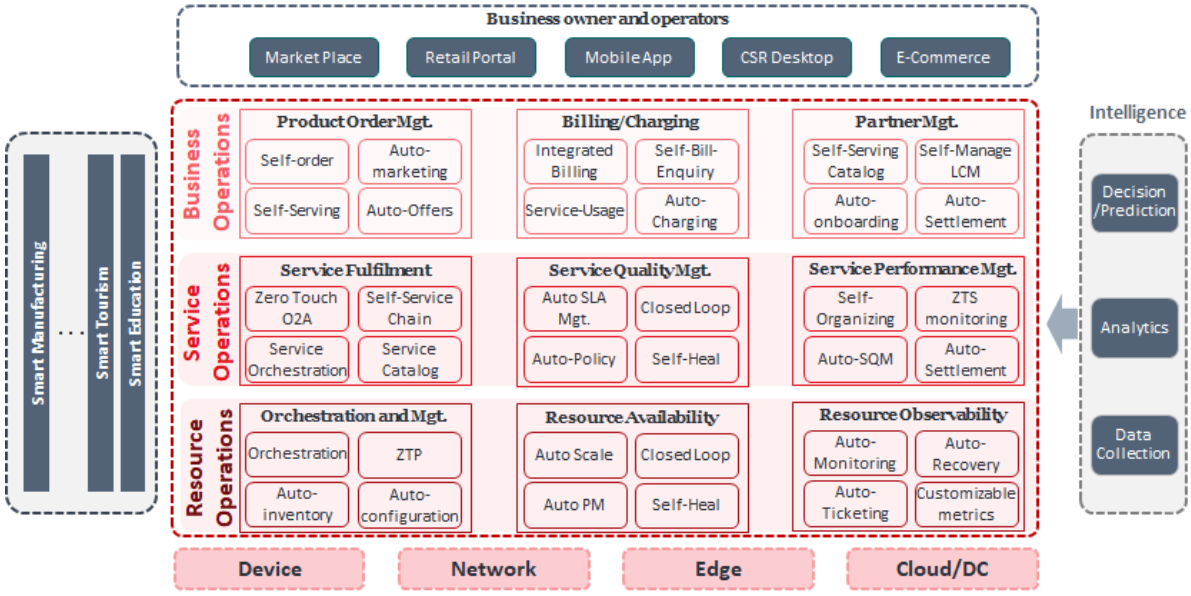

Figure 5 AN Technical Architecture

The above diagram captures the proposed B/OSS architecture for the new "AN", clearly segregated into 4 distinct layers-

Channel – This layer presents the self-serving capabilities and provides the communication medium for end users to interact with the rest of the "AN" system. For e.g. end users like an education institute or an individual student can place an order via a Marketplace or service provider's web portal or even the service provider's own CSR team can use this layer while supporting and troubleshooting end users tickets

Business Operations (BO) – This layer presents the Business rules and Business Intents for enabling self-governing & self-fulfilling capabilities to facilitate zero-friction services towards their end users and business partners. It defines the master product catalog, which will drive the business intent decomposition into service intent (CFS & RFS) and to centrally manage the autonomous order management process i.e. zero touch provisioning, self-fulfillment and autonomous order-2-activation.

Service Operations (SO) – This layer represents autonomous service life cycle management comprising of policy driven service instantiation, autonomous service orchestration, zero touch service chaining, self-service assurance, self-healing etc. to govern the accurate translation of service intents to resource intents.

Resource Operations (RO) - This layer represents autonomous resource management functions to self-monitor, self-optimize and self-heal the physical, virtual and logical resources to fulfil the resource intents and to address the customer requirements. RO defines and governs the resource instantiation, configuration, resource life cycle management (LCM) and performance metrics.

7. Proof of Concept

7.1. Scope of the PoC

PoC focusses on transforming Smart Education to be Autonomous & Self-sustained. While there are several use cases within Smart Education, for this PoC AR/VR based Smart Learning is selected as the area of focus. AR/VR based learning is selected as it enables immersive learning & personalized visual experience, understanding real-world scenarios from a remote location and collaborative learning. Within AR/VR based smart learning, Autonomous Order to Activation flow depicted below is selected as the first use case to present proof of concept of AN framework.

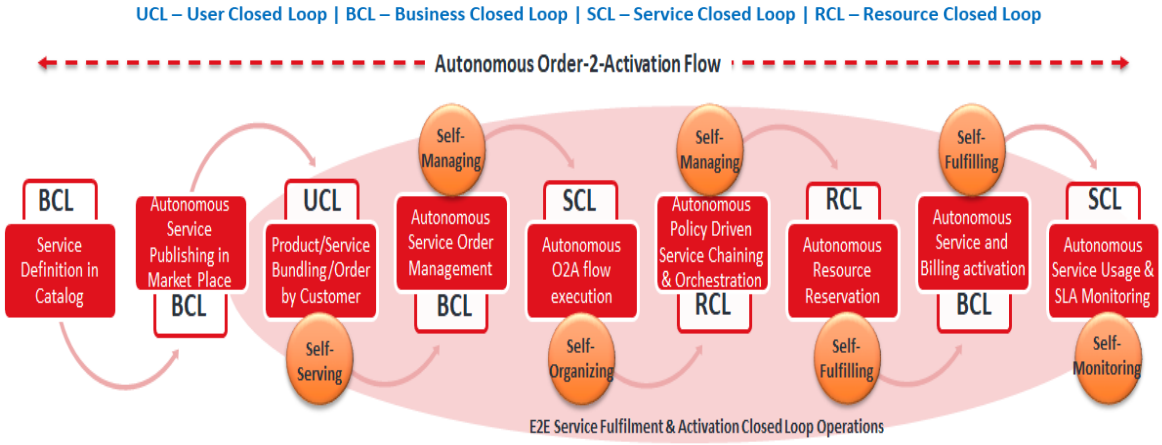

Figure 6 Smart Education - Autonomous O2A flow

7.2. Use Case

When it comes to 5G/IoT/NextGen Network, there are plenty of applications in Smart City, Smart manufacturing, Smart Healthcare, Smart Automotive and Smart Grid. Smart Education is gaining interest on what is possible in the classroom and in remote learning, especially with pandemic like scenarios. The future learning model will be an immediate, virtual, and interactive environment which enables students to learn and interact in different ways than they do today. VR and AR will play a big role in providing quality education and improving understanding-based learning and reversed classroom techniques among students and teachers. While the AR/VR ecosystem is diverse with multiple stakeholder involved from devices, gateway, connectivity, edge to cloud platform and application providers along with different end users, the table below captures the AR/VR use case and the ecosystem requirements from one of the personas – The STUDENT view.

Perquisite – AR/VR Service Definition

This section focuses on AR/VR service definitions based on types of AR/VR service offering to target audience, e.g. VR games, VR 360º, VR live broadcast or VR education. Each of these different services offer varied experience to end users and hence needs to be defined in the system with appropriate QoS/QoE parameters and SLAs. For e.g. to support 8k VR services, key parameters like frame rate (@120 FPS), Coding (H.265), Transmission technology (Sphere or FoV), Data rate (@200-500 Mbps) and Latency (<= 15ms) to be supported by the ecosystem.

Scenario – AR/VR Service Ordering and Zero Touch Service Order 2 Activation & Billing

This section focuses on Autonomous Networks and systems capabilities from providing a seamless and one-touch AR/VR service ordering to autonomous service fulfilment and activation. The section defines various modules within the B/OSS ecosystem that needs close integration – Product Catalog to Marketplace, Product Catalog to Service Catalog to Resource Catalog, Inventory, Provisioning, Policy and Orchestration. AN system provides seamless exchange of information between these modules and ensure self-x capability when it comes to optimization, assurance and healing.

Table 3 Smart Education AR/VR O2A Use case flow

As a Student I want	Requirements	AN Services	Classification	Closed Loop	Common or Specific AN Service
Quality of Service					
AR/VR based uninterrupted streaming experience (static / mobility@ speed	Throughput- 4K/360^0 : 10:50 Mb 8K/360^0 HDR/ stereoscopic Video: 50:200 Mb 6DoF/FVP:0.2:5 Gb Latency - ~5-10 ms	Service Definition MQI, IQI,PQI	Self-Optimizing	Business Closed Loop	New Innovative Specific
Order Management & Billing					
To easily order the AR/VR plug-	Integrated Order & Service catalogue	Market Place for Services Bundling	Self-Ordering	Business Closed Loop	New Innovative Specific

n-play service bundles		Product/Service Bundling and ordering by customer	Self-Ordering	User Closed Loop	New Innovative Specific
		Zero touch O2A Workflow	Self-Organizing	Business Closed Loop	New Innovative Specific
		Policy Driven Service Orchestration	Self-Managing	Service Closed Loop	New Innovative Specific
		Autonomous Resource Orchestration & Reservation	Self-Managing	Resource Closed Loop	New Innovative Common
		Autonomous Service and Billing activation	Self-Managing	Business Closed Loop	New Innovative Specific

7.3. Business processes and sequence diagrams

Section 8.1 "From Business Ecosystem to Business Architecture" clearly captures the Business processes across the functional layer from service ordering to service fulfilment & activation. It highlights 2 key aspects – A. Existing B/OSS systems or modules and modules those will be required to be specifically adapted/enhanced to support AN self-x capabilities. Considering the targeted architecture defined in section 6.3, below sequence diagram captures one of the scenario defined in section 7.2 above.

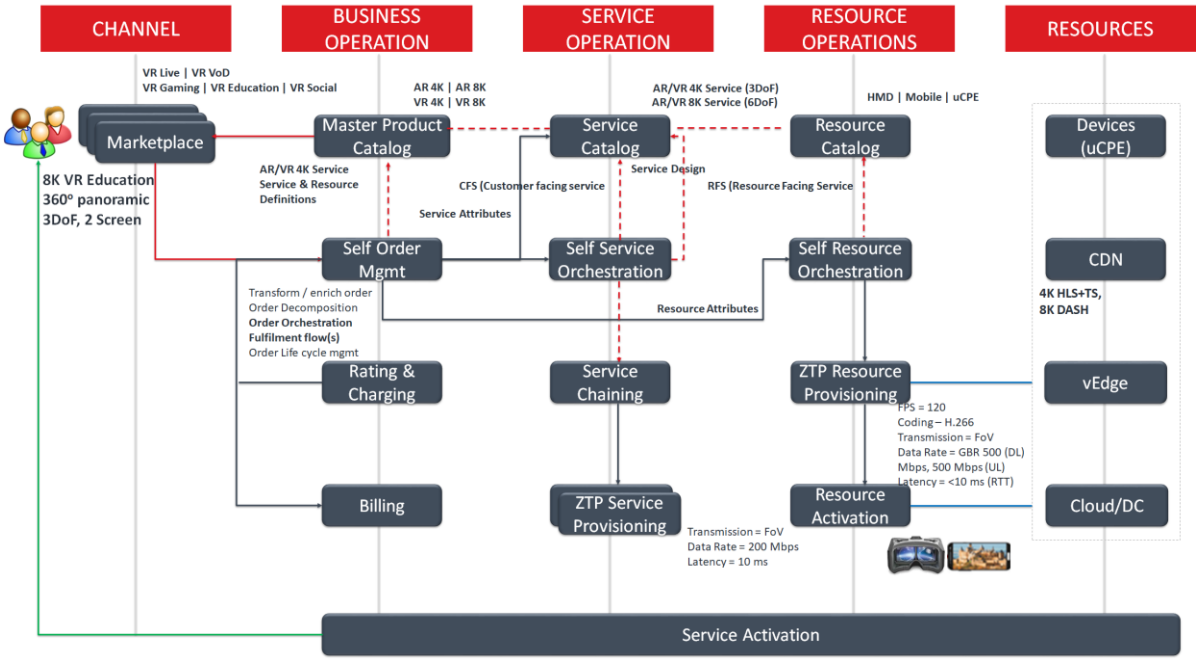

Figure 7 Smart Education O2A Sequence Diagram

7.4. PoC Applications Components description and exposed interfaces

When a student connects to an edge node requesting access to a virtual class, a notification (**Intent**) triggers the following workflow where

1. The customer tenant is created
2. The product order is automatically generated
3. 2 service orders are triggered to
    a. Deploy the VR application on the edge node
    b. Configure the network resources to provide the connectivity
4. The underlying resources are automatically activated and provisioned.
5. The user is dynamically notified (**User closed loop**)

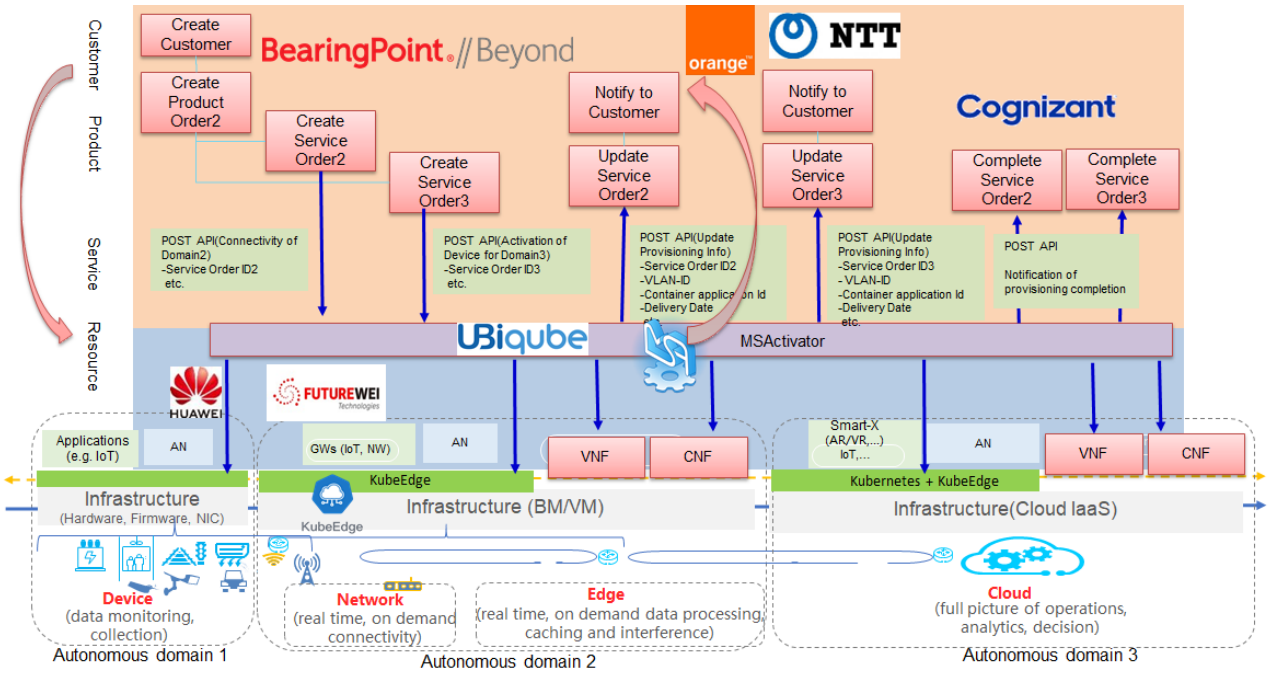

Figure 8 AN for Smart Education - Implementation Architecture

The whole architecture was designed by Cognizant and is composed of the following building blocks:

- **Customer and product management:** BearingPoint//Beyond Infonova Digital Business Platform is a cloud-native digital platform designed to help CSPs introduce new business models and drive new revenue by experimenting, launching and monetizing new offerings at speed. It enables CSPs to collaborate, co-innovate and co-invent with a partner ecosystem and introduce new solutions that better meet customers' needs, while starting small and scaling up with success. It supports multiple business partners on a single platform, allowing them to easily and dynamically exchange, combine and monetize new solutions with new technologies and partners (e.g. OTT, TV, 5G or IoT). The platform's advanced business orchestration and monetization capabilities – enabled by an advanced billing engine, flexible catalog and comprehensive order and fulfillment functionalities – are available to all business partners in the ecosystem.
- **Service and resources management:** MSActivator is the leading Integrated Automation Platform (IAP) engineered by UBiqube for the continuous design of any IT infrastructure automation process. It is composed of Integration and Automation Modules. The Integration Module is used by infrastructure engineers to onboard / integrate the wide spectrum of related vendors and systems involved in any given IT solution, i.e. cloud technologies (public/private, containers, etc.), networks systems (virtual and physical, optical, 5G, etc.), security systems, IoT systems and devices, etc… The Automation Module provides the IT automation developer with a unified development environment for process design without concern for the underlying infrastructure technologies / vendors used, enabling an evergreen design.
- **Edge application management:** KubeEdge is a CNCF Incubation project, built upon Kubernetes and provides fundamental infrastructure support for network, application deployment and metadata synchronization between cloud and edge KubeEdge provides Seamless Cloud-Edge Communication for both metadata and data, autonomous operations of Edge even during disconnection from cloud; works in constrained resource situations (low memory, low bandwidth, low compute); easy communication between application and devices for IOT. In this architecture, KubeEdge provide the Edge-Cloud PaaS, supports Cloud-Native Kubernetes style automation at scale, auto-deploy, self-healing, auto-scaling, logging, resource quotas, constrained resource, etc. It provides same experience as using a Cloud Kubernetes Cluster, seamlessly support Kubernetes Applications and monolithic application in either VM or container formats. It supports all mainstream Linux OS at edge site, e.g. Ubuntu, Centos etc.

  The implementation will further be enhanced by integrating Business Operations & Service Operations either by leveraging existing TM Forum APIs or by developing new APIs which will be contributed back to TM Forum. As a subsequent step real IoT AR/VR based Smart Education use case will be integrated for E2E demonstration.

  The architecture will further leverage the Network Function Virtualization concepts to enable dynamic deployment and termination of network and security functions by orchestrating VNF and/or CNF. VNF and CNF orchestration are yet mandatory but are not enough to fulfil the vision of Autonomous Networks. Network and security policies will have a huge impact when it comes to auto-scaling of network resources based on traffic demand. The proposed architecture will ensure Network and security policies are automated across the physical and virtual elements to allow seamless end-to-end auto configuration, orchestration and automation all the different autonomous domains (cloud, network, edge)

8. Contribution to TMF

TM Forum starts the Autonomous Networks Project (ANP) since August 2019 and has published two documents: IG1193 – Vision & Roadmap [2], and IG1218 AN business requirements & architecture [3]. In addition, the 2nd release of AN white paper "Autonomous Networks: Empowering Digital Transformation for Smart Societies and Industries" [6] is published in October 2020.

This catalyst has implemented the key elements of AN framework e.g. closed loops, self-x operating capabilities, and the smart education use case and solution have been accepted in the AN whitepaper as well as IG1218 V1.1 as the example of use case solutions for enabling the digital transformation of vertical industries with innovative services.

It is planned to continue this project in conjunction with the development of ANP, including but not limited to the APIs to support the intent interaction, the AI for intelligent autonomous domains and closed loop operations with more Smart-X applications.

9. Conclusions and Outlook

We are planning a multiyear sequence of think, design, build, and operate prototypes of Autonomous services for verticals. The ambition is to capitalize cycle after cycle to develop a full autonomous framework. We will define then a new blueprint that will be used to allow new ZeroX capabilities and then help domains to create/maintain revenues even within crisis periods.

10. References

[1] TM Forum Whitepaper, Autonomous Networks: Empowering Digital Transformation For The Telecoms Industry (Rel. 1), May 2019.

[2] TM Forum Document, IG1193 Cross-Industry Autonomous Networks – Vision and Roadmap v1.0.1, October 2019.

[3] TM Forum Document, IG1218 Autonomous Networks Business Requirements and Architecture v1.0, July 2020.

[4] TM Forum Catalyst project, Autonomous Network Hyperloops, 2020.

[5] TM Forum INFORM newsletter, Developing autonomous networks hyperloops to create new networks and services, September 2020.

[6] TM Forum Whitepaper, Autonomous Networks: Empowering Digital Transformation For Smart Societies and Industries (Rel. 2), Oct 2020.

[7] TM Forum Document, IG1218 Autonomous Networks Business Requirements and Architecture v1.1, October 2020.