TM Forum Introductory Guide

Autonomous Networks Business Requirements and Framework

IG1218

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Executive Summary

This document provides business requirements and business framework of services and infrastructure supported by Autonomous Networks, including the user requirements per user stories, key business capabilities and framework, and related key metrics for measuring autonomous levels, as well as new business models of production, ecosystem, collaboration. In addition, examples of the lifecycle of Services are illustrated for understanding the usage of business requirements and framework.

This document serves as the general guideline for pertinent work streams and work items, including user stories and use cases, technical architecture and interface/APIs specs, PoCs/catalyst projects, testing and verification, as well as industry collaboration. Moreover, it will be used as the baseline for the marketing plan, campaign, social events and public whitepaper on behalf of the TM Forum and member companies.

In order to guide the development of Autonomous Networks, a top-to-down, user-centric and business driven approach is used to derive the general business requirements and define overall business framework for formulating some common services and capabilities of Autonomous Networks. The common Autonomous Networks Services are categorized into five types as the matrix of business growth & operational efficiency, as well as automation & autonomy:

- Business growth:

  1. Network services automation e.g., VPN, SD-WAN, 5G connectivity

  2. Autonomous ICT services e.g., network + cloud + edge

  3. Autonomous digital enabling services e.g., ICT services + platforms (operations, collaboration)

- Operational efficiency:

  4. Network operations automation e.g., predefined services and operations

  5. Autonomous Networks operations e.g., platform based, dynamic process, flexible production operations

The key requirements of business framework of Autonomous Networks are as follows:

- The basic business metrics of Autonomous Networks is called “Zero-X” experience, which specify the overall characteristics of Autonomous Networks services including zero-wait, zero-touch, zero-trouble and zero-friction. The measure of autonomous level of AN service is based on the autonomy (automation + intelligence) of E2E lifecycle of the services from customer perspective, rather than the technology and/or element implementation.
- The fundamental ingredients of Autonomous Networks are simplified infrastructure, closed loops, autonomous domain, intent driven interaction. The simplified infrastructure is the fundament of Autonomous Networks, which implies fewer layers, fewer hops in the context of network architecture, less complicated protocols, more automated network management & operations. The closed loop is the core operation of Autonomous Networks, which represents the full lifecycle of related business, including user/business/service/resource closed loops. The user closed loops is the main thread to streamline and drive the E2E lifecycle of services. Autonomous Domains are the basic logical business entities to expose network resources/functionalities as services/capabilities in support E2E lifecycle of automated intelligent network/ICT services.

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Intent based interaction is the main mechanism in support of closed loops across different layers.

- Self-operation (Self-X) capabilities are the main functions to support above business requirements, which include self-serving (self-planning/design, self-ordering, self-marketing), self-fulfilling (self-organizing, self-managing, self-governing), and self-assuring (self-monitoring/reporting, self-healing, self-optimizing), and so on.

This release of the document enhances IG1218 V1.0 that mainly serves as the overall skeleton and high level business requirements and framework. The rapid iterative approach is used to further the details in the future releases.

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Introduction

The ultimate goal of Autonomous Networks is to enable the digital transformation and seamless service experience of vertical industries and consumers through Autonomous Networks/ICT services, meanwhile improve the operational efficiency of the telecom/ICT industry through automated, intelligent close loops of operations.

Obviously, it requires the ecosystem & collaboration across the industries, among the service providers, suppliers, and integrators, as well as the customers. The main drivers of the ecosystem and collaboration are the business value and customer experience enabled by the autonomy of Autonomous Networks, which can offer a simplified, easy-to-use and dynamic network/ICT services and capabilities. Therefore, a user-centric, business driven, top-to-down approach is essential to the success of Autonomous Networks.

The Autonomous Networks should focus on the innovative, common and open methods to minimize the complexity, cost and fragmentation, and maximize the flexibility, efficiency and experience of telecom/ICT services and infrastructure. It is of necessity to depict the requirements and characteristics of common services of Autonomous Networks, and autonomous levels of AN services; the architectural functionalities and capabilities support the above services, which they serve as the common business languages for all partners to communicate and collaborate.

The term Autonomous Networks describes the telecom system (including management system and network) capabilities that can be self-operating with minimal to no human intervention. Autonomous Networks essentially is an integrated set of programmable systems, bring high-value and personalizing experience for customers, support CSP to improve efficiency, enable innovation, and increase revenue, with overall network agility, security and resiliency. It is essential to derive a set of general business requirements and offer common business framework and capabilities for various user scenarios, and more importantly a set of key metrics to measure the autonomous levels of those business capabilities following the same criteria of overall autonomous levels defined in vision document.

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Intended Audience

As we have indicated in the introduction it is essential that the design and development of Autonomous Networks is not perceived to be confined to the telecommunications industry, but they must be developed to support a much wider cross industry ecosystem that enables telecommunications service providers to participate in, and actively support, the digital transformation of many different industries.

This paper is targeted at business decision makers across all industries undergoing digital transformations, as well as being of particular relevance to CIO's, CTO's together with their architects and designers from both IT and networks backgrounds as we are seeing the consolidation of software thinking across the worlds of IT systems and networks.

This document will also position the TM forums work on business requirements and framework of Autonomous Networks in relation to other standards organizations so that it is unambiguous as to the role that each organization will play in the development of the solutions going forward.

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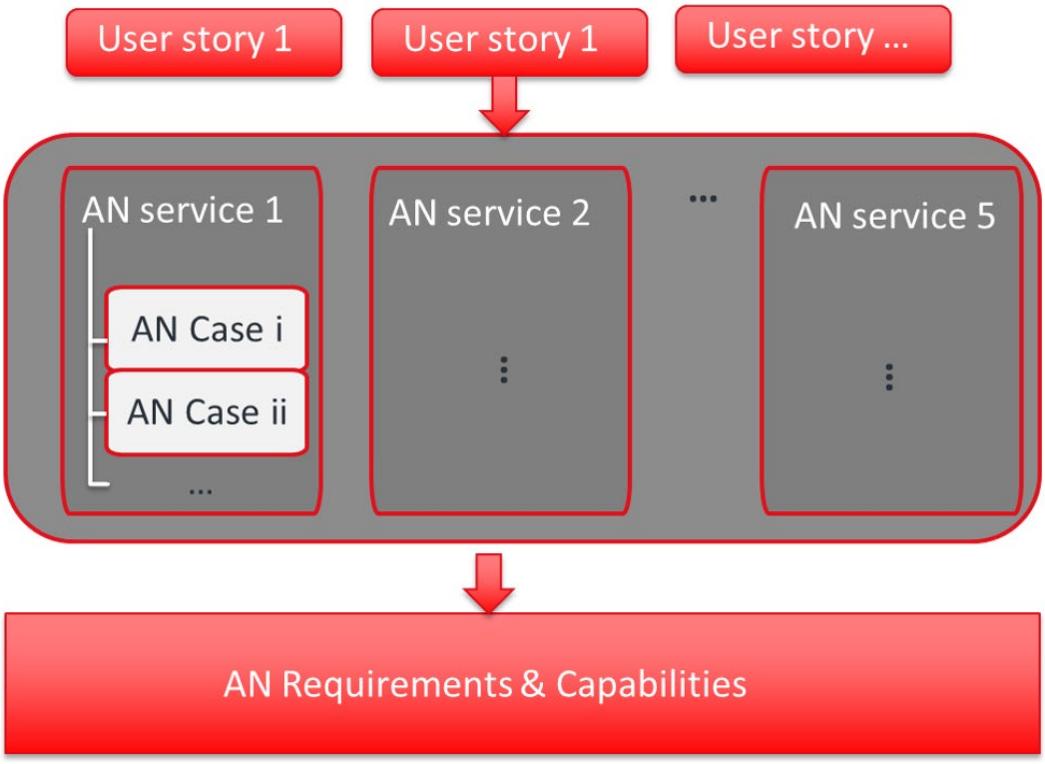
1. Methodology

This clause describes the overall development method of Autonomous Networks.

Methodology of Business requirements & capabilities development

The basic method is to use a user-centric, top-to-down, business driven and rapid iterative approach to develop all contents of Autonomous Networks:

- **User-centric**: follow the end users (vertical industries, CSPs' business owners and consumers) business logic to collect user stories (e.g., smart city, smart manufacture, self-driving car)
- **Top-down**: Each Autonomous Networks (AN) Service shall represent the full lifecycle of the network/ICT service required by the certain type of users (multiple user stories) ,based on the Autonomous Networks framework, which the full lifecycle process can be expanded and analyzed from top to down. **Business driven** identify business requirements and capabilities to distill business metrics and define business framework.
- **Rapid Iterative approach**: illustrate the user scenarios, reference solutions and catalyst project for Autonomous Networks per select AN case and refine business requirements and frameworks.



* AN Cases describes components of lifecycle of AN services

Figure 1. ***Methodology of Business requirements & capabilities development***

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The step-by-step process to develop business requirements and framework of Autonomous Networks is as follows:

1) **Start with user stories:** collect and describe how AN is used from the end user perspective

2) **Generalize as AN services:** define and describe full lifecycle of common AN services

3) **Compose of multiple AN case:** demarcate and describe key steps/capabilities of full lifecycle of common AN service as AN case, which maps the AN service to the operation process and Autonomous Networks framework.

4) **Distill common requirements and framework**: summarize and normalize the common business metrics and capabilities in conjunction with autonomous levels, which is also used to as the inputs for technical architecture and implementations.

Distill key business requirements, metrics and capabilities

It is crucial to distill common business requirements, metrics and capabilities for AN service based on various user story scenarios. The following table illustrates the basic approach and relationship between user stories, AN services and common business requirements, metrics and capabilities. Further details are described in clause 2.

Table 1*. Distill key business requirements, metrics and capabilities from user stories/autonomous services/cases*

Business Category	User Stories	AN services	AN cases	AN Requirements & Capabilities			
				User closed loop	**Business closed loop**	**Service closed loop**	**Simplified infrastructure/ autonomous domains**
Business Growth	Vertical industrie s	1. Automated network services e.g. VPN, SD-WAN, 5G slicing	1; 2.; 3.; ...	✓ Requirements 1. 2. 3. 4. ... ✓ Metrics 1. 2. 3. 4. ... ✓ Capabilities 1. 2. 3. 4. ...	✓ Requirements 1. 2. 3. 4. ... ✓ Metrics 1. 2. 3. 4. ... ✓ Capabilities 1. 2. 3. 4. ...	✓ Requirements 1. 2. 3. 4. ... ✓ Metrics 1. 2. 3. 4. ... ✓ Capabilities 1. 2. 3. 4. ...	✓ Requirements 1. 2. 3. 4. ... ✓ Metrics 1. 2. 3. 4. ... ✓ Capabilities 1. 2. 3. 4. ...
		2. Automated ICT services	1., 2., 3. ...				
		3. Automated digital enabling services	1., 2., 3.,...				
Operations Efficiency	Telecom internal	1. Existing operations automation	1., 2., 3.,...				
		2. Innovative agile operations	1. , 2., 3.,...				

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2. Business vision and models

2.1. Business vision

According to the Autonomous Networks Whitepaper [1,2,3] the business vision of Autonomous Networks is to provide innovative ICT services and capabilities with “Zero X” (zero wait, zero touch, zero trouble) experience for the users of vertical industries and consumers, which makes them simpler to consume by the users, and leaves the implementation complexity with the providers.

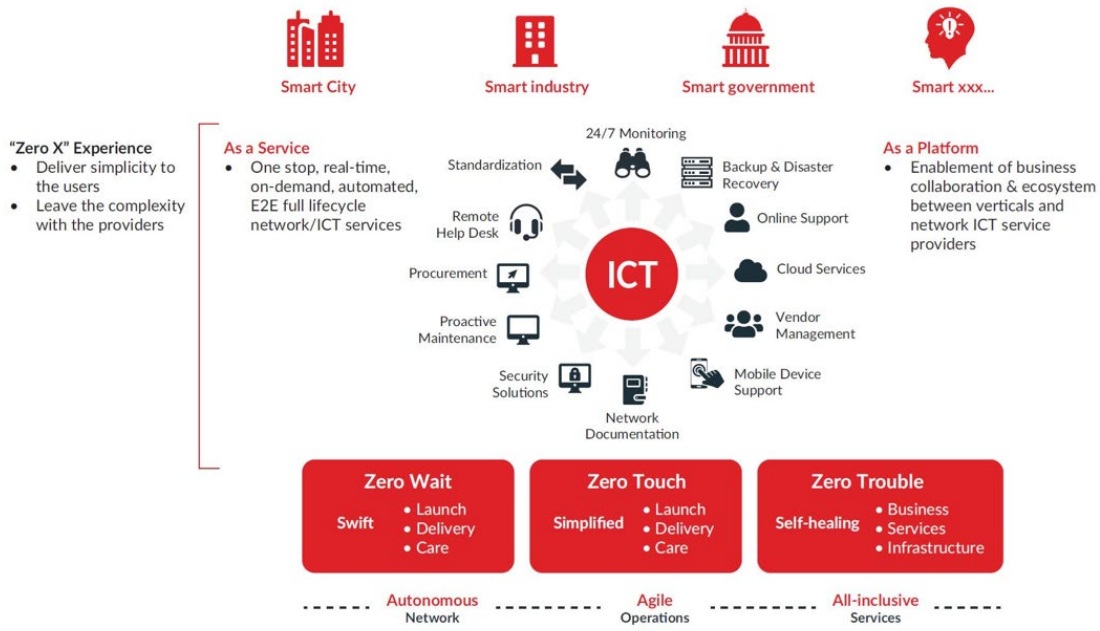

Figure 2. ***Opportunities to ICT Industry***

Obviously, Autonomous Networks are able to provide two types of innovative services:

- As a Service: One stop, real-time, on demand, automated, E2E full lifecycle network/ICT services
- As a platform: Enablement of business collaboration & ecosystem between verticals and network/ICT service providers

They can also enable highly automated business and network operations of “zero x” experience for innovative services as well as existing services.

Therefore, Autonomous Networks should focus on the following objectives for the “Zero x” experience Network/ICT services through transformation and innovation of production & commercialization and architecture & operations of the telecom/ICT industry:

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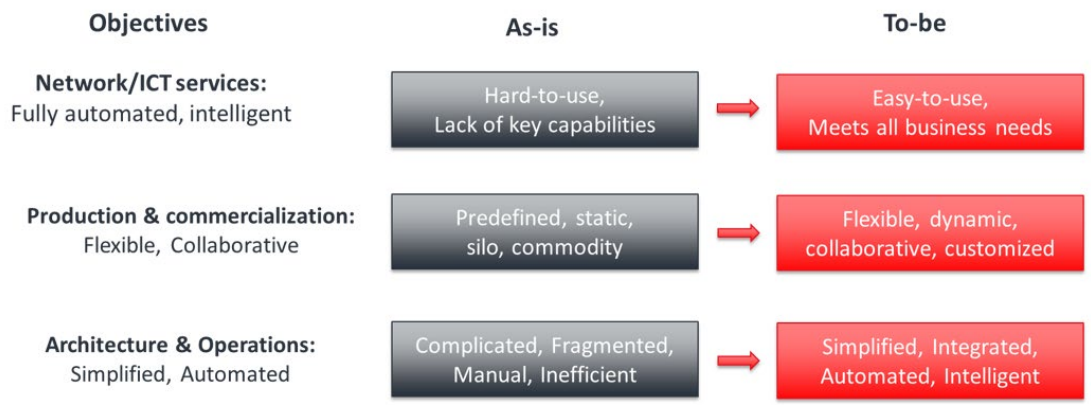

Figure 3. ***Objectives of Autonomous Networks***

As described in the vision document [4], Autonomous Networks aim to provide fully automated zero wait, zero touch, zero trouble innovative network/ICT services for vertical industries users and consumers, and support self-configuration, self-healing, self-optimizing and self-evolving telecom network infrastructures for telecom internal users: planner, service/marketing, operations and management, which:

- Consist of simplified network architecture, virtualized components, automating agents, intelligent decision engines and self-dynamic capabilities to create intelligent business/network operations for the closed loop of new digital business, which,
- Offer disruptive services for innovative user experience, critical services based on fully automated lifecycle operations and self-organizing, dynamic optimized resource.
- Aim to provide fully automated zero wait, zero touch, zero trouble innovative, critical network/ICT services for vertical industries users and consumers, and
- Support self-operating (self-serving, self-fulfilling, and self-assuring) network/ICT infrastructures and services for enabling digital transformation of vertical and telecom industries through full lifecycle of operations.

2.2. Business models Support

The ultimate goal of Autonomous Networks is to upgrade the telecom market structure with simplified, automated and intelligent ICT/network services that will enable the digitalization of various industries and consumers. In order to achieve this objective, it is essential to transform the existing business models to some new production, business and collaboration models:

- **Digital partner collaboration and ecosystem model:** all partners will collaborate to form partner ecosystem for offering on demand, personalized and real time services and capabilities to the customers, which is different from traditional customer-provider-supplier model, AKA everything as a service.
- **Collaborative production model:** in order to achieve a new partner ecosystem, a collaborative production model is pivotal to leverage the best-suit solutions using best breed technologies through win-win benefit sharing collaboration.

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- **Knowledge-as-a-service operations model**: in order to enable collaborative production, the operations knowledge should be shared and monetized through a common platform as an enabling service.

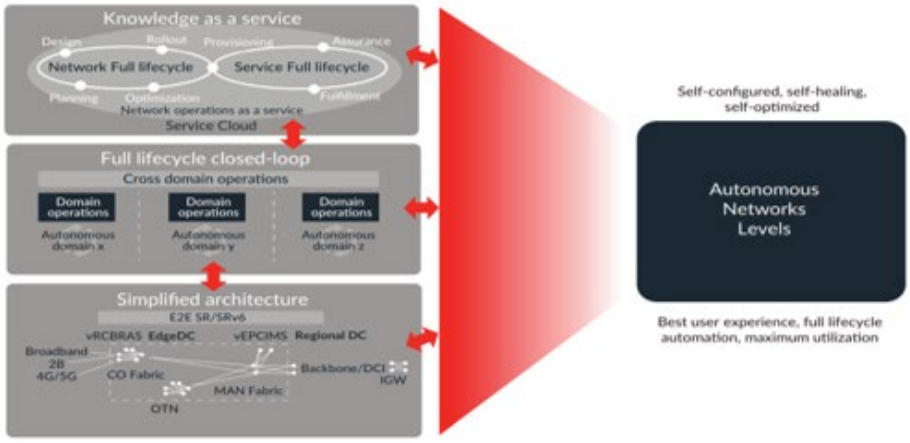

Figure 4. ***New models enabled by Autonomous Networks***

Autonomous Networks enables above business models through self-x operating (self-serving, self-fulfilling, and self-assuring) capabilities, which streamline the business collaboration of ecosystem partners by the common autonomous levels.

Roles and Responsibilities of Autonomous Networks:

In the context of Autonomous Networks, responsibilities regarding AN must be clearly defined and assigned to roles. The roles related to AN include:

- Communication / business Service Customer (CSC): Uses communication services.
- Communication/business Service Provider (CSP): Provides communication services. Designs, builds, and operates its communication services. The CSP provided communication service can be built with or without network .
- Network Operator (NOP): Provides network services including CFS services and RFS services. Designs, builds, and operates its networks to offer such services.
- Domain Network Solution Provider (NSP): Supplies resource closed-loop solution to NOP and CSP.
- OSS or BSS solution provider: Provide services closed-loop operation solution or business closed-loop operation solution to CSP and NOP.

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3. User story scenarios and AN services

3.1. Focused user stories

The Autonomous Networks start off with a focus on the following user stories (but not limited to these scenarios):

Table 2. ***Focused user stories and examples of use cases***

#	Use stories	Example use cases
1	Smart city	Future IoT in the City; eHealth - Remote Surgery, Olympus Cameras; Drones as a Service; Financial Services, Insurance - “Just-in-time insurance”; Traffic Congestion/Management ;
2	Smart manufacturing	Smart Factories – Private Network; Smart Factories - production monitoring, Lift Company Schindler, Telefonica IoT & DC Connectivity, BT IPConnect; Remote Trouble Shooting – Maintenance; Smart Electric Power Network;
3	Autonomous Vehicles	Connectivity (5G) + Edge + Cloud synergy; Mobility as a service
4	Media/entertainment (sports event, gaming, remote production)	Gaming; “Pop-up” Network for Music Festivals, for new Housing Estates; AR/VR – Digital Tourism “Historical Building” –”Bath";
5	Public safety (information casting, disaster recovery)	Disaster management - Emergency Services, e.g. -Verizon First Responders / 5G Riders -BT Emergency Team – Balloon Base Station – Portable Tower
6	Efficiency 1: automated O&M	E2E automation of network O&M, troubleshooting, alerting, prediction, recovery, for example home broadband, DC Energy saving, One trouble ticket one network fault
7	Efficiency 2: innovative services	Connectivity as a Service; Guaranteed BB At Home using 5G; Enterprise Customer Portal; SLA/SLO with Business Partners - Service Supplier, SLA for Financial private line, SLA for Home online class

3.2. Common Autonomous Networks/ICT services

Based on above user story scenarios, some categories of common Services are proposed:

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Table 3. ***Categories of Autonomous Networks services***

AN Services	Business Growth (Vertical industries)	Operations Efficiency (Telecom industry)
Services Automation	**1. Network services automation** e.g., VPN, SD-WAN, 5G connectivity	**4. Network operations automation** e.g., predefined services and operations
Autonomous Services	**2. Autonomous ICT services** e.g., network + cloud + edge **3. Autonomous digital enabling services** e.g., ICT services + platforms (operations, collaboration)	**5. Autonomous Networks operations** e.g., platform based, dynamic process, flexible production operations

Business growth:

- Services automation (to improve user experience and increase revenue for existing services) i.e., AN service 1: full lifecycle of network service automation.
- Autonomous services (for Innovation of new digital services and new revenue) i.e., AN service 2: full lifecycle of autonomous ICT service, and AN service 3: full lifecycle of autonomous digital enabling service

Operational efficiency:

- Services automation (to improve operation efficiency and internal user experience of existing operation automation,), i.e., AN service 4: Pipeline operations: full lifecycle of network operations automation
- Autonomous services (to improve operation efficiency of Innovative operations,) i.e., AN service 5: Flexible agile operations – full lifecycle of automated flexible agile operations.

The detailed descriptions of Autonomous Networks services in Table 4 are mainly for the purpose of reference and illustration. The commercialization and deployments of exact AN service may vary per business disposition of different service providers.

Table 4. ***Definition of Autonomous Networks services***

Business Category	User's stories	AN services	Descriptions	Example AN cases
Business Growth	Vertical industries (enterprise) e.g., smart city, smart manufacture, self-driving car, Smart Electric Power, SLA for Financial private line	**1. Network services automation** e.g., VPN, Private line, SD-WAN, 5G connectivity	Full lifecycle of network service automation, including service planning & design, offering, operating as well as security & availability assurance, etc.	1. Automated service offering; 2. Automated service provisioning; 3. Automated service assurance; 4. RPA (Robotic Process Automation) for full lifecycle of

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Business Category	User's stories	AN services	Descriptions	Example AN cases
				network service; …
		2. Autonomous ICT services e.g., network + cloud + edge,5G E2E slice for Smart Electric Power	Full lifecycle of on demand ICT service automation, including user interaction, service request & development, service launch, service fulfillment and assurance, etc.	1. AI assisted user interaction (voice/chatbot) for search, order and reporting; 2. Real-time service monitoring; 3. E2E automated control & management of network-cloud-edge resources; …
		3. Autonomous digital enabling services e.g., ICT services + **platforms** (operations, collaboration)	Full lifecycle of digital enabling service automation, including digital customer experience enabling, E2E Product lifecycle management, Automated and simplified partner onboarding and license management, E2E lead to cash automation, Flexible rating and discounting including complex multipartner settlements, etc.	1. Intelligent self-service touchpoints; 2. Collaborative digital marketplace; 3. Automated partner onboarding & management; 4. Marketing & sales automation; 5. Cross-layer closed loop of service fulfillment and assurance …
Operations Efficiency	Telecom Marketing, operations and network & IT personnel e.g., One trouble ticket for one network fault, Energy saving, Private line	**4. Pipeline operations automation** e.g., predefined services and operations Automatic network fault root cause analysis, Automatic installation and	Full lifecycle of existing business process, e.g., SIP + Operations defined by Business Process Framework aka eTOM	1. personalized customer promotion; 2. Automated performance monitoring & assurance; 3. Predictive network failure and availability; …

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Business Category	User's stories	AN services	Descriptions	Example AN cases
	for the financial industry, Home online courses	deployment of 5G base stations, DC Energy saving		
		5. Flexible agile autonomous operations e.g., platform based, dynamic process, flexible production, SLA commitment for private line, SLA commitment for home broadband application services(e.g., Home online class, Game, Video conference)	Full lifecycle of on demand agile operations process e.g., design-thinking, AIOps, DevOps	1. Real time network provisioning and assurance; 2. Predictive network failure and recovery; 3. RPA for full lifecycle of network operations…

3.2.1. Key requirements of AN services

Per business vision of Autonomous Networks, "Zero X" experience are the key metrics of AN services. A high level breakdown of the "Zero X" metrics is listed in Table 5.

Table 6 is intended to illustrate the key business characteristics of AN services to serve the SLA purpose.

Table 5. ***Key user experience of AN services: zero wait, zero touch, zero trouble, zero friction, zero trust***

	Zero wait	Zero touch	Zero trouble	Zero trust	Zero friction
Key user experience	- Launch - Delivery - Care	- Operations - Development - Maintenance	- Infrastructure - Business - Service	- Protection anywhere	-On boarding -Integration, e.g., partner systems

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Table 6. ***Business characteristics of AN services (SLA)***

	Experience	Availability	Security
Key Business characteristics	- Real time - On demand - Personalized	- Always on	- Risk free

3.3. Roles and Responsibilities of Autonomous Networks

In the context of Autonomous Networks, responsibilities regarding operations have to be clearly defined and assigned to roles. Similar as defined by [5], the roles related to AN include:

- AN Service Customer (ANSC): Uses AN services
- AN Service Provider (ANSP): Provides AN service at various levels of operations per AN framework, i.e., at business, service and resource levels, to design, build and operate its AN service. The ANSP provided AN service can be built with or without underlying infrastructure.
- AN Solution Provider (ANSOP): Supplies AN solution. It could be at autonomous domain level with or without underlying infrastructure. The underlying infrastructure could be virtualized or physical elements.

Depending on actual scenarios:

- Each role can be played by one or more organizations simultaneously.
- An organization can play one or several roles simultaneously.

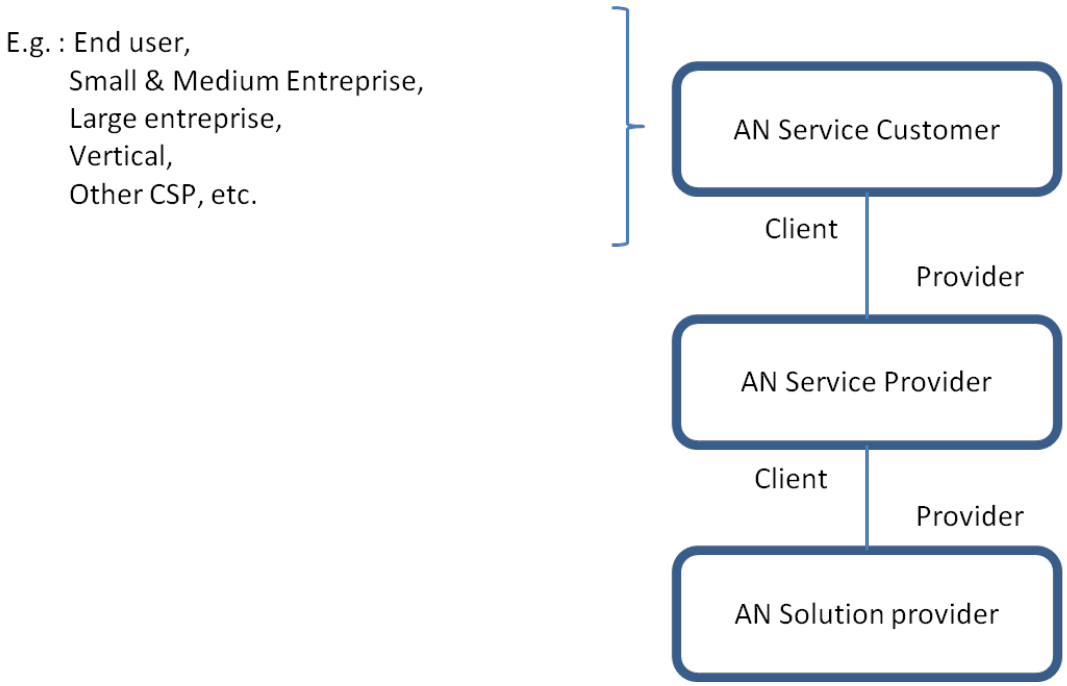

Figure 5. ***High-level model of AN roles***

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4. Autonomous Networks Framework and Capabilities

4.1. Autonomous Networks Framework

The framework of Autonomous Networks identifies 3-layers + 4-closed loops:

3-layers: are common capabilities of operations that can be utilized to support all scenarios and business needs:

- **Resource operations layer**: mainly provide network resources and capabilities automation in each autonomous domain level.
- **Service operations layer**: mainly provide the capabilities for network planning, design, rollout, provisioning, assurance and optimization operations across multiple autonomous domains.
- **Business operations layer**: mainly provide the capabilities for customer, ecosystem and partner business enabling and operations for Autonomous Networks services

4-closed loops: to fulfill the full lifecycle of the interlayer interaction

1) **User closed loop**: the interaction across three layers and three closed loops to support the user service fulfillment.
2) **Business closed loop**: the interaction between business and service operations, which may trigger related service and resource closed loops in its fulfillment.
3) **Service closed loop**: the interaction between service and network resource operations,
4) Which may trigger related resource closed loops in its fulfillment.
5) **Resource closed loop**: the interaction of network resource operations in the granularity of autonomous domains.

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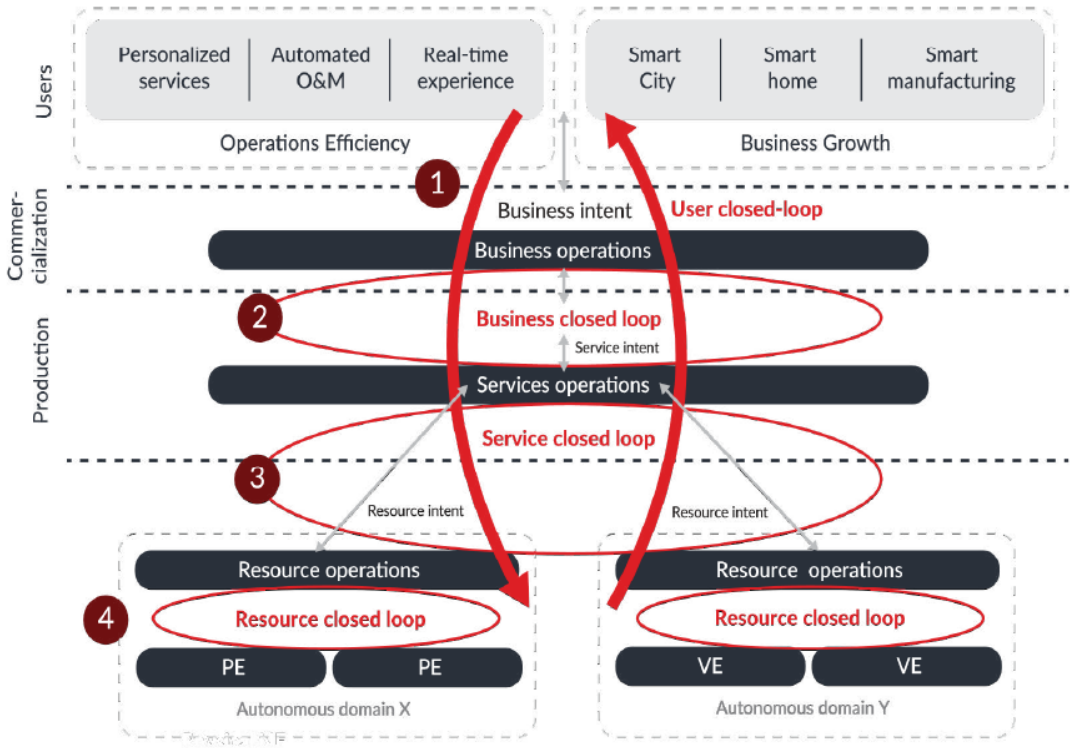

Figure 6. ***Autonomous Networks Framework***

Autonomous Network Framework as shown above illustrates the rationale of correlation and interaction among the closed loops of different layers:

- User closed loop is the main thread to streamline the business/service/resource closed loops.
- Each business/service/resource closed loop is to address the interaction between adjacent layers.
- The interaction between adjacent layers is to be simple, business driven and technology/implementation independent, i.e., communicating and fulfilling the intents (business/service/resource) rather than technology-prone commands based the intent mechanisms and interfaces.
- The different intents are used for the interactions of different layers, i.e., business intent, service intent and resource intent.

4.2. Autonomous Networks Levels

As described in clause 1, through analyzing a collection of user stories, common Services are defined as the template of the service offering, which is further developed with AN business requirement and capabilities. The autonomous levels are used as the common model and metrics to measure and fulfill the AN service, and corresponding business requirements (customer experience, SLA) and key capabilities across the industry ecosystem and partners (e.g., customer, CSP, solution provider and integrator etc.).

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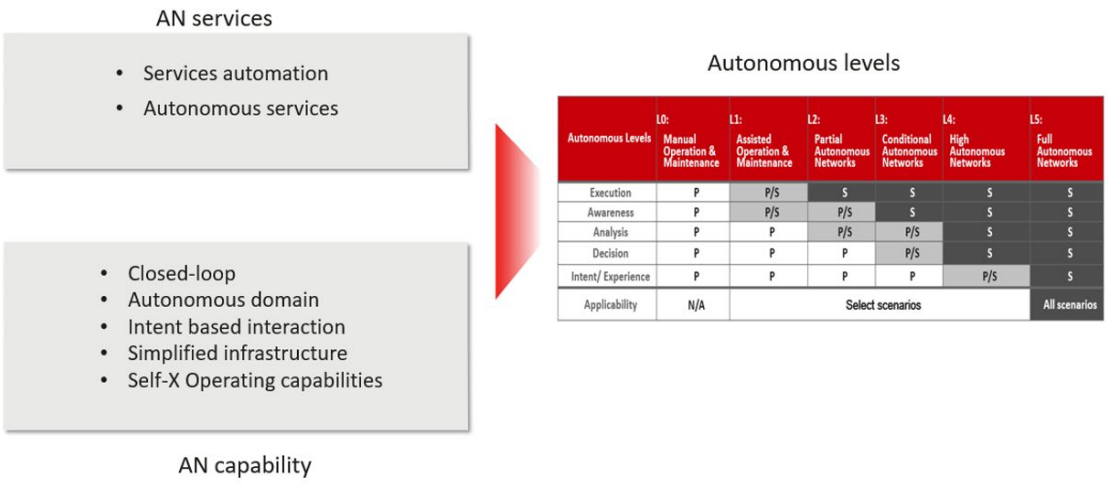

Figure 7. *Autonomous levels for AN services and capabilities*

In order to measure and fulfill customer experience and SLA, the corresponding autonomous levels will be defined, which are used to guide the improvement of network automation & intelligence, evaluate the value and benefits of AN services capability, and guide the intelligent upgrade of CSP and vendors.

The driving force for defining the autonomous levels:

- Align the AN concept: telecom industry conforms a unified understanding of AN, and promotes a consistent understanding of the value of different levels of AN.
- Align the roadmap of AN capability: telecom industry reaches a consensus on the development of AN capabilities, driving the industry ecosystem to develop according to the roadmap.

The categorization of AN Levels is illustrated in Table 7. The basic criterion is that the autonomous levels of AN services are based on the closed loops of business lifecycle and value, for instance, if the closed loop is only fulfilled at the element level, it is at most in Level 1; if the closed loop is fulfilled at the E2E full lifecycle of select AN service, it is in Level 4.

Table 7. *Levels of Autonomous Networks*

Autonomous Levels	L0: Manual Operation & Maintenance	L1: Assisted Operation & Maintenance	L2: Partial Autonomous Networks	L3: Conditional Autonomous Networks	L4: High Autonomous Networks	L5: Full Autonomous Networks
Execution	P	P/S	S	S	S	S
Awareness	P	P/S	P/S	S	S	S
Analysis	P	P	P/S	P/S	S	S
Decision	P	P	P	P/S	S	S
Intent/ Experience	P	P	P	P	P/S	S
Applicability	N/A	Select scenarios				All scenarios

P People (manual) S System (autonomous)

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- **Level 0 - manual management:** The system delivers assisted monitoring capabilities, which means all dynamic tasks have to be executed manually.
- **Level 1 - assisted management:** The system executes a certain repetitive sub-task based on pre-configured to increase execution efficiency.
- **Level 2 - partial Autonomous Networks:** The system enables partial automatic O&M for certain units based on predefined rule/policy under certain external environments.
- **Level 3 - conditional Autonomous Networks:** Building on L2 capabilities, the system with awareness can sense real-time environmental changes, and in certain network domains, optimize and adjust itself to the external environment.
- **Level 4 - high Autonomous Networks:** Building on L3 capabilities, the system enables, in a more complicated cross-domain environment, analyze and make decision based on predictive or active closed-loop management of service and customer experience-driven networks.
- **Level 5 - full Autonomous Networks:** This level is the goal for telecom network evolution. The system possesses closed-loop automation capabilities across multiple services, multiple domains, and the entire lifecycle, achieving Autonomous Networks.

The evaluation process of AN levels requires setting up baselines and identifying weaknesses to formulate phase-specific objectives and improvement strategies. Operation task baselines are defined based on Table 7 from the perspective of the entire O&M process (planning, construction, maintenance, optimization and operations). For each operation task, generic technological requirements and level evaluation rules are defined from the domain and service perspective, providing a reference for defining and instantiating domain-specific ANL.

4.3. Key requirements of AN capabilities

Autonomous Networks should support the following capabilities:

Table 8. Key capabilities:

Simplified infrastructure	The simplified infrastructure is the fundament of Autonomous Networks, which implies fewer layers, fewer hops in the context of network architecture, less complicated protocols, more automated network management & operations.
Closed loop	The closed loop is the core operations of Autonomous Networks, which represents the full lifecycle of related business, including user/business/service/resource closed loops.
Autonomous domain	Autonomous domains are the basic logical business entities to expose network resources/functionalities as services/capabilities in support E2E lifecycle of automated intelligent network/ICT services.
Intent driven interaction	Intent driven interaction is the main mechanism in support of closed loops across different layers.
Self-X operating capabilities	Self-X operating capabilities are considered in support of single-layer/domain operations and cross-layer closed loops in the context of Autonomous Networks.

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Full-stack AI	AI capabilities need to be provided at different layers of Autonomous Networks to support AI-based automated closed-loop network operations and implement intelligent automation in different service scenarios.

4.3.1. Closed loops

4-closed loops: to fulfill the full lifecycle of the interlayer interaction

1) **User closed loop**: the interaction across the above three layers and three closed loops to support the user service fulfillment. The interactions across the different layers should be based on simple, intent based API interfaces.
2) **Business closed loop**: the interaction between business and service operations.
3) The operations need to be upgraded from isolated business to on demand, automated business collaboration and ecosystem, which enables the closed loop for customer/business/ ecosystem operations, normally requiring collaboration across multiple service providers globally.
4) **Service closed loop**: the interaction between service and network resource operations.

   The operations need to be upgraded from legacy customized project-centric approach to a data/knowledge driven platform based on full lifecycle operations automation. The most important part is a mindset change from a “build-and-operate” to a “design with operate”, and the recognition of the value of operations knowledge as a service (KaaS). KaaS is about delivering the right knowledge to the right person in the right context at the right time via desktop, laptop or any mobile device. Operations automation sits at the core of production efficiency and business agility.

5) **Resource closed loop**: the interaction of network resource operations in the granularity of autonomous domains.

The network needs to be upgraded from fragmented, siloed network element level integration towards a closed loop of network autonomous domain with extremely simplified network architecture, which lay the foundation for the closed loop of network operations and collaborative production by means of cross autonomous domain collaboration.

4.3.2. Autonomous domains

Services involve multiple layers and closed loops. Autonomous domains serve as the basics unit that can fulfill the closed-loop automation of the lifecycle of specific network operations of Autonomous Networks based on the business disposition of network functions and operations . This reduces technical complexity and conceals the variations of different vendor implementations, thus supporting E2E business requirements of AN services.

The boundary of autonomous domains is based upon the network operation requirements and business decision of each CSP. The instantiation of autonomous domain can be defined by CSP based on the factors such as service types, network technologies, deployment locations, and maintenance organization relationship. The examples of autonomous domain instances can be the closed loops of access, metro backbone, core, edge, customer network from infrastructure perspective, or SD-WAN, VoLTE, CDN etc. from service perspective.

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The basic principles of the operations of autonomous domains are:

- Autonomy of individual autonomous domain: each autonomous domain runs in self-operating mode per business objective and hides the details of domain implementation, operations and the functions of the domain elements to the users of autonomous domains, with local intelligence and localized knowledge.
- Collaboration of cross autonomous domain: multiple instances of autonomous domains can be collaborated by upper layers service operations using the intent driven interaction to fulfill the lifecycle of network/ICT services.
- Closed Loop Automation: automation uses closed loop mechanisms to assure service experience by completing workflow steps and continuously adapting to ensure goals and objectives are met. The control loop adjusts and adapts itself, keeping the system in the desired state.

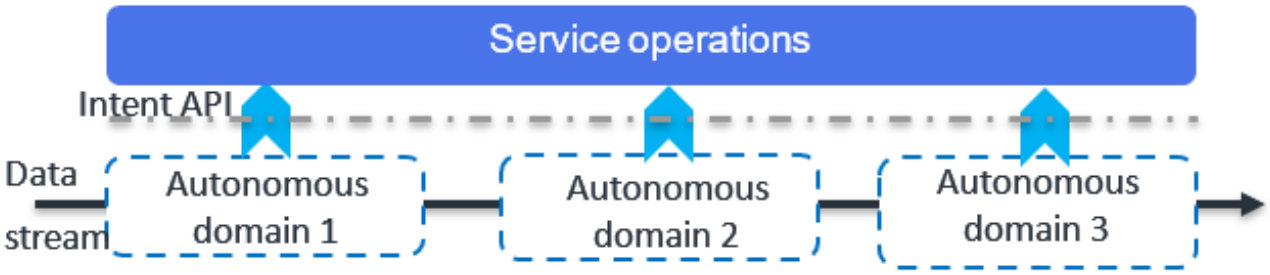

Figure 8. ***Principles of autonomous domains***

The key characteristics of autonomous domains:

- Can model the exposure of network and service capabilities as a platform and/or services to enable higher-level business services to utilize network capabilities at the domain level instead of element level.
- Can specify a set of rules at the business level (e.g., Service level availability, service level guarantee based on response times, repair times etc.) that can be automatically monitored and effected across all domains of the architecture in support of closed loops.
- Can be instantiated per business dispositions that represent network operations of the future e.g., access, edge, core, network services and so on.
- Each instantiation can be decoupled from another and expose a set of domain-based services via common intent driven interaction/ Open APIs to upper layer or other domains.
- Can be easily nested and integrated by external management systems. For example, data reporting and query capabilities are provided externally. Programmable management service mechanisms allow users to customize data formats, facilitating interconnection with various external management systems and managing various devices.

4.3.3. Intent driven interaction

Autonomous Networks need to be able to adapt their operation to the business objectives of the operator as well as expectations of customers and users. The role of intent is to communicate all these expectations to the Autonomous Networks. Intent

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establishes machine processable knowledge about goals, targets, requirements and constraints.

Intent defines **what** Autonomous Networks are expected to achieve, but it leaves the details of **how** a network is designed and operated to the internal operations of the network platform. This means that the smart software on the platform can constantly optimize how the service is delivered, and we can incrementally add new technologies like Analytics and Machine Learning to constantly improve the implementation.

Intent is comprehensible: It must be understandable by humans, while being formally and unambiguously specified to be processable by machines. It must be comprehensive in what it specifies for matching the semantics within autonomously operated domain, and the scope of autonomously operated tasks.

Intent is declarative: It leaves room for the Autonomous Networks to explore options for finding the optimal solution. Intent declares the wanted results rather than prescribing a specific solution. Ideally, intent expresses a utility level goal that describes the properties of a satisfactory outcome rather than requiring a specific outcome.

Intent is infrastructure agnostic and portable: The expectation expressed by intent originates from contracts and business strategy. It does not change if the underlying system is replaced or modified. While implementation and capability differences between system vendors will continue to exist, intent can be ported between system generations and implementations.

Intent is complete: Intent defines all goals and expected behavior. If it is not specified as intent, it is not a goal the system needs to consider. This also means that concerns that were common sense in human operated systems would need to become explicitly expressed as intent.

Intent is composable: Multiple intents are given to the Autonomous Networks, and it is expected to consider them altogether. Unlike traditional software systems, where requirements are analyzed offline to detect and resolve conflicts prior to implementation, intents are added during run-time. Therefore, an essential capability of an autonomous system would be to detect and resolve conflicts.

Intent is persistent: Intent is valid as long as the goals and requirements it expresses are relevant. For example, an intent that specifies a service needs to be delivered would not become invalid once the service is initially provisioned. Intent is rather the reason for keeping the service operational and assure its performance. Therefore, intent has a life cycle that is actively managed by the user or function that has generated it.

Intent is measurable: It uses measurable and ideally standardized metrics to define the target state. This allows automated evaluation of success as well as identification of issues and optimization opportunities.

Intent is layered: It is layered with Business, Service and Resource Intent. Business Intent as the top layer. Service in the middle and Resource in the bottom layer. Layered intent mechanism drives interaction across these 3-layered intents in supporting closed loops to deliver Self-X experience.

For Autonomous Networks, the Intent-interaction model is a must, not optional. The role of Intent is beyond relieving the burden of the user knowing implementation details. More importantly, it sets the autonomous system's internal goal. And the system then takes proactive actions to achieve the stated goal based on its observation of the environment. So intent is the fundamental mechanism to utilize the service of the Autonomous Networks.

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Intent represents the concerns and objectives of the users of an Autonomous Network. It therefore varies with the diversity of user types and roles:

- **Business intent** represents the objectives of a business user. This includes for example the delivery of a custom application defined by SLA. Operators expect their Autonomous Networks to operate service contracts while meeting revenue targets. Their customers expect a good user experience.
- **Service intent** represents the objectives of a service user. A service is expected to deliver functional as well as non-functional attributes. This includes targets, for example on connectivity, bandwidth, latency or availability.
- **Resource intent** represents the objectives of resource users. Resources are expected to be allocated so that performance and quality of service targets are met.

This indicates that intents target a great variety of concerns across Autonomous Networks Architecture. Therefore, the handling of intent is distributed throughout the Autonomous Networks layers and autonomous domains. The interactions between different layers are through intent APIs. For example, business intent would be handled in business operation and resource intent would be handled within the autonomous domain that matches the concerns addressed by the intent. An intent handling function is the basic architectural building block to assemble intent based operation. Figure 11 shows the intent handling function with its intent API. The diagram also illustrates by example how various instances of intent handlers are allocated across the layers and functional domains.

Intent can originate directly from user input through frontend portals. Additional intent would be derived automatically, for example from contracts and service orders. An intent handling function would operate its domain by analyzing the discrepancy between the observed state of the network and the wanted state expressed by intent. The main task of intent handling would be to close this gap as much as possible. It determines the optimal operational state according to all given intent and then acts to transition the network into this state. This process includes the resolution of inevitable conflicts between intent through prioritization and optimization.

The intent handling function can act by defining the goals of neighboring or subordinate domains through further intent. Furthermore, for all intent that is given to an intent handler, it is expected to report progress and status back to the source of the intent. This closes a loop. The intent mechanism is therefore instrumental for creating control loops throughout the Autonomous Networks Architecture.

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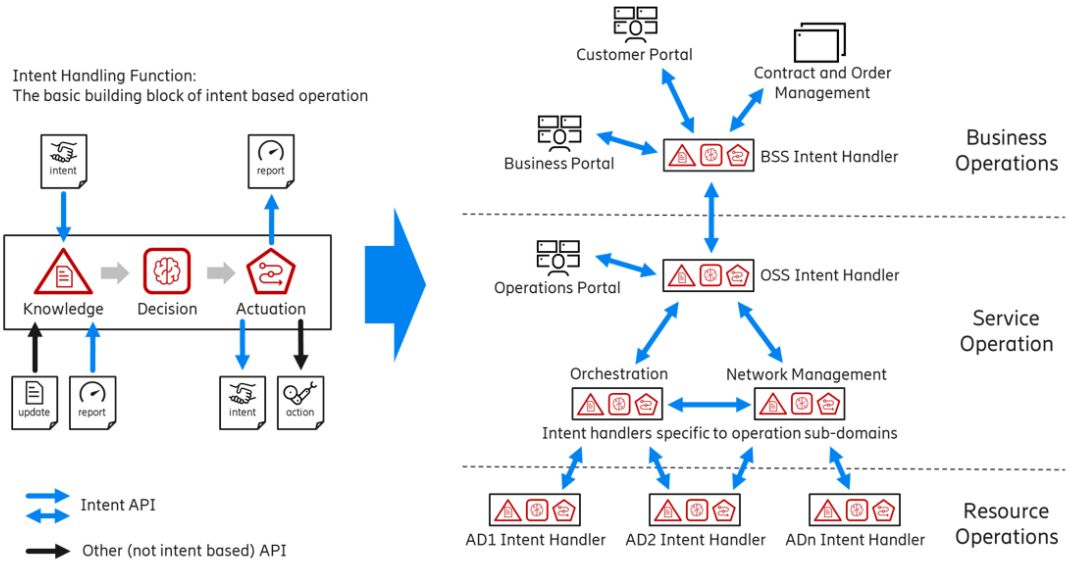

Figure 9. ***Autonomous Networks operation based on intent handling***

4.3.4. Simplified infrastructure

The simplified infrastructure fundamentally guarantees an intelligent and hierarchically Autonomous Networks. The simplified network architecture, protocols, devices, sites, and deployment solutions offset complexity caused by ultra-high bandwidth and vast connections, improving efficiency and customer experience throughout the network lifecycle. For instance, the network is flattened, and the complexity of network maintenance is reduced by simplifying network layers. Simplified network protocols facilitate network configuration and maintenance. Services are decoupled from the physical network, adapting to different service scenarios on one network and allocating network resources on demand. The unified cloud platform supports cloud-based transformation of multiple service systems, IT systems, and related scenarios and processes.

Meanwhile, more real-time sensing components and AI inference capabilities are introduced to network devices for making them smarter. In this way, the digital sensing capability of resources, services and surrounding environments has been enhanced, edge intelligence capabilities such as sensing analysis and decision execution are provided at the data source. For instance, AI models are injected to the networks through cloud collaboration for online inference, the networks are capable of automated fault analysis, locating, and predictive parameter adjustment, devices can be capable of multidimensional real-time awareness and data reporting, as well as working with the management and control platform to implement real-time network visualization and minute-level fault discovering.

4.3.5. Self-X Operating capabilities

In order to support the full lifecycle of user closed loop, the key capabilities are categorized in a tiered manner. Although those capabilities may be applied to the operations within a single layer/domain, they are mainly considered in support of the cross-layer closed loops in the context of Autonomous Networks.

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Table 9. Self-Operating (Self-X) capabilities requirements

Categories	Sub-categories
Self-serving	**Self-planning/capability delivery**: provides the customization (DIY) capabilities of network/ICT service planning, design and deployment
	Self-ordering: provides the online, digitalized and/or one-click ordering capabilities of network/ICT services
	Self-marketing: provides the automated marketing activities for general and/or personalized campaign/promotion
Self-fulfilling	**Self-organizing**: provides the collaboration of business/service/resource intent delivery
	Self-orchestration: provides the orchestration and schedule of business, services, and resources intent delivery
	Self-configuration: provides configuration and activation of businesses, services, and resources intent delivery
Self-assuring	**Self-monitoring/reporting**: provide the automatic, continuous monitoring and alerting in real time
	Self-healing: provides the recovery of SLA e.g., performance, availability and security in real time
	Self-optimizing: provides the optimization of SLA e.g., performance, availability and security in real time

4.3.6. Full-Stack AI in Autonomous Networks

On Autonomous Networks, AI can be used anywhere as needed. Similar to a human brain in terms of perception, training, inference, decision-making, and execution processes, AI capabilities need to be provided at different layers of Autonomous Networks. Autonomous Networks are developing towards full-stack AI.

- **Business operations layer:** Customer- and business-oriented AI focuses on implementing intelligent applications for various business processes, including precision marketing, customer intent translation, customer experience, and flexible combination of products and offerings.
- **Service operations layer:** AI oriented to service intents and cross-domain collaboration focuses on implementing intelligent applications for various service processes, including service intent translation, E2E resource orchestration and scheduling, SLA policy production, and E2E fault and performance management.
- **Resource operations layer:** AI in an autonomous domain is responsible for local lightweight development, model retraining, and AI asset management, efficiently implementing generalization and iterative optimization of local intelligence, and supporting intelligent perception, analysis, decision-making, and execution on local networks. NE AI can comprehensively detect network status in real time and perform inference, improving device-level autonomous analysis and processing.

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Effective collaboration of AI at each layer can complete more complex AI tasks. This will support AI-based automated closed-loop network operations and implement intelligent automation in different service scenarios to reach higher Autonomous Networks levels.

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5. Autonomous Networks Operations

The purpose of this chapter is to illustrate the lifecycle of AN operations per AN services and cases as depicted in Chapter 2.2.2 Table 3&4. It is classified into two types: service automation and autonomous services.

From the AN Operations lifecycle perspective, the general relationship of AN key business capabilities (Zero-X, Self-X) and AN service with Autonomous Network Levels is as follows:

- In Level 0 Zero X and Self-X business capabilities are not applicable
- In Level 1 Zero X and Self-X business capabilities are only available to individual element.
- In Level 2 Zero X and Self-X business capabilities are available to standalone AN cases that are not streamlined to AN service
- In Level 3 Zero X and Self-X business capabilities are available to select AN case that are part of AN service
- In Level 4 Zero X and Self-X business capabilities are available to E2E full lifecycle operations of select AN services
- In Level 5 Zero X and Self-X business capabilities are available to E2E full lifecycle operations of any AN services

The following sections illustrate the lifecycle of AN operations and related key business capabilities in conjunction with different AN level.

5.1. Existing service automation

The following type of AN services mainly enables the automation and intelligence of the lifecycle of existing services for the purpose of efficiency improvement and customer experience:

- AN service #1: existing network service automation
- AN service #4: existing pipeline network operations automation

The full lifecycle of existing network operations is normally based on the process of SIP + Operations, which is in line with eTOM.

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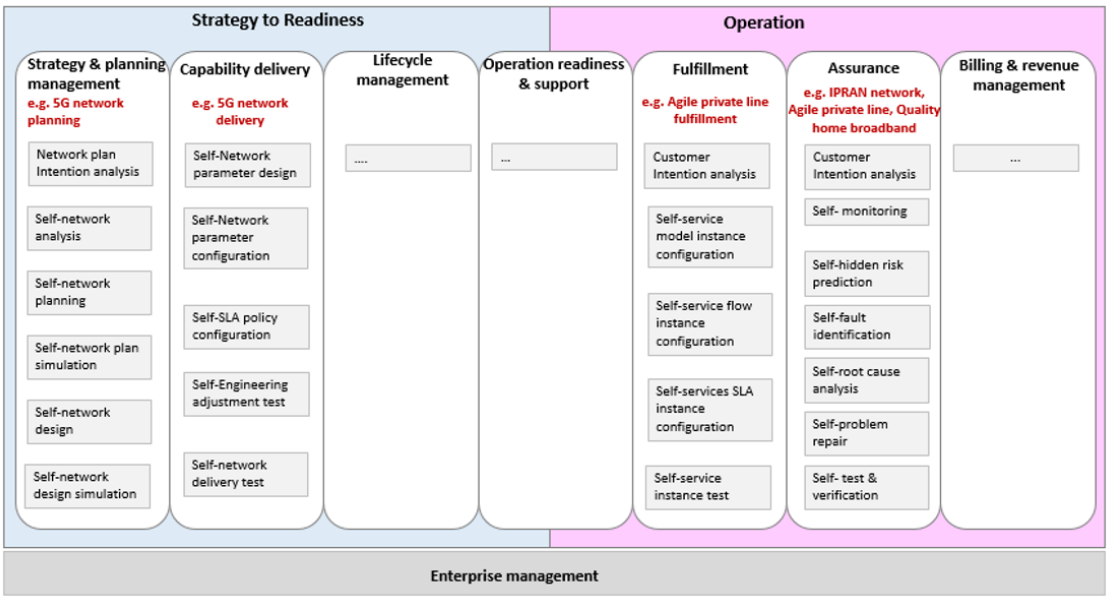

Figure 10. ***Full lifecycle of existing network services: SIP + Operations***

The detailed capabilities are as follows:

1. Self-Planning

	Automation/intelligence capabilities	**Description**
Self-planning e.g., network planning	Network plan Intention analysis	Automatically analyze network planning parameters.
	Self-network analysis	Automatically analyze network status and development needs, output insight analysis.
	Self-network planning	Automatically realize network planning
	Self-network plan simulation	Automatically performs network plan simulation verification.
	Self-network design	Automatically realize network design.
	Self-network design simulation	Automatically performs network design simulation verification.

2. Self-capability delivery

	Automation/intelligence capabilities	**Description**
Self-capability delivery **e.g., 5G network delivery**	Self-Network parameter creation	Automatically create network parameters and network assurance policy.
	Self-Network parameter design	Automatically senses that the network device is online and implements parameter configuration.

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	Automation/intelligence capabilities	Description
	Self-SLA policy configuration	Automatically configures the network SLA policy
	Self-Engineering adjustment test	Automatically finds the network anomalies and corrects errors.
	Self-network delivery test	Automatically check the network and corrects errors.

3. Self-Fulfillment

	Automation/intelligence capabilities	Description
Self-Fulfillment **e.g., Agile lease line fulfillment**	Customer Intent analysis	The customer's intent input, the system automatically converts
	Self-service model instance configuration	Automatically query and allocate resources, implement service model parameter configuration.
	Self-service flow instance configuration	Automatically implement service process flow parameter configuration.
	Self-services SLA instance configuration	Automatically implement service SLA policy parameter configuration.
	Self-service instance test	Automatically verify services instance and generate reports, automatically find services anomalies, and automatically correct.

4. Self-Assurance

	Automation/intelligence capabilities	Description
Self-Assurance **e.g., IPRAN network, Agile lease line, Quality home broadband**	Customer Intent analysis	Automatically convert customer intent into monitoring rules.
	Self- monitoring	Automatically monitoring the services or network alarm and KPI, etc.
	Self-hidden risk prediction	Automatically predicts and analyzes the services or network KPI /KQI degradation.

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	Automation/intelligence capabilities	Description
	Self-fault identification	Automatically and accurately identifies abnormalities.
	Self-root cause analysis	Automatic root cause analysis and automatic find root cause location.
	Self-problem repair	Automatically generate the services or network recovery solutions, automatic decision-making optimal plan, automatically realizes the recovery.
	Self- test & verification	Automatically verify services instance or network, generate test reports, automatically find services or network anomalies, and automatically correct.

5.2. Innovative autonomous services

The ultimate goal of autonomous services is to organize, manage, orchestrate and govern the corresponding processes, capabilities and interactions of business/service/resource closed loops in real time, on demand, customized and automated Self-X operating manner (based on the business policy and assisted intelligent analytics and decision) that provide “Zero-X” experience.

The following types of innovative services may apply the new lifecycle of design-test/runtime as shown in Figure 7:

- AN service #2: Autonomous ICT services
- AN service #3: autonomous digital enabling services
- AN service #5: Autonomous Networks operations

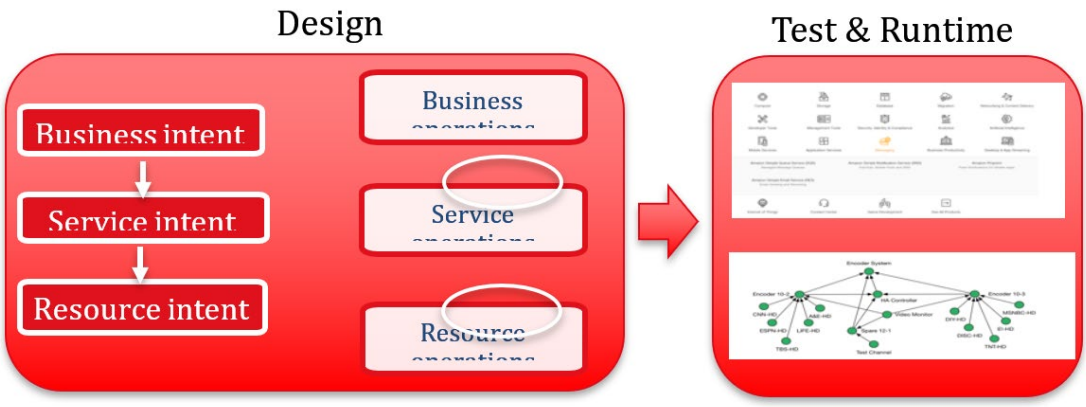

Figure 11. ***Full lifecycle of innovative autonomous services: design, test & runtime***

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It may consist of the following steps:

Design: business intent → service intent → resource intent mapping

1. Identify E2E service domains and closed loops that participate in a service chain
2. Map customer requirements and experience requirements to : WHAT-IF scenarios

Testing: SLA validation

3. Program all resolution path, exception handling and escalations
4. Create chaos monkeys to randomly throw exceptions and test the services
5. Establish SLA

Runtime: orchestration, assurance & optimization

6. Allocate the resources on demand
7. Monitor, prevent and provision the SLA in real time
8. Optimize the usage per SLA

Some cases are illustrated in IG1218A [11] and further realization studies are in IG1218C[12].

5.3. Effectiveness indicators

It is important to measure the business value and service effectiveness of AN in terms of service growth, customer experience and operations efficiency. The value of these indicators lies in two aspects:

1) Visualizing and quantifying the effectiveness and benefits of AN evolution and

2) Aligning the development of autonomous capabilities with the enterprise strategy and service development trend.

Effectiveness indicators are selected based on the Zero-X and Self-X visions. Effectiveness indicators and ANL are two key AN evaluation factors that jointly facilitate the fulfillment of the AN vision.

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7. Administrative Appendix

7.1. Document History

7.1.1. Version History

Version Number	Date Modified	Modified by:	Description of changes
0.1	15-Oct-2019	Dong Sun, W. George Glass	Initial Version
0.2	04-Dec-2019	Dong Sun	Added business requirements
0.3	02-Feb-2020	Dong Sun	Added business architecture and the appendix of use cases for operations automation
0.4	10-Mar-2020	Dong Sun	Added business capabilities, use case for autonomous ICT services, and refined business architecture
0.5	15-Jun-2020	Dong Sun	Refined the structure of the doc; add some detailed description of the key requirements; replace the use cases of Chapter 3.1 and Appendix I. Ready for final review.
0.6	24-Jun-2020	Dong Sun	Accepted all the work in progress revisions, including the edits from Dave Milham.
0.7	28-Jun-2020	Dong Sun	Included the edits from Huawei. Start final review.
0.8	01-Jul-2020	Dong Sun	Included the edits from China Unicom.
0.9	07-Jul-2020	Dong Sun	Final edits per the review comments
0.99	08-Jul-2020	Dong Sun	Final draft after team review
1.0.0	12-Jul-2020	Alan Pope	Final edits prior to publication
1.0.1	06-Sep-2020	Dong Sun	Initial draft to V1.0
1.0.2	11-Sep-2020	Wang Xu	1st contribution
1.0.3	20-Sep-2020	Wang Xu	2nd contribution
1.0.4	20-Sep-2020	Dong Sun	Final draft with revision marks for team review
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2.0.0	28-May-2021	Alan Pope	Final edits prior to publication
2.1.0	26-Nov-2021	Alan Pope	Final edits prior to publication
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7.1.2. Release History

Release Number	Date Modified	Modified by:	Description of changes
Pre-production	12-Jul-2020	Alan Pope	Final edits prior to V1.0.0 publication
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Production	24-Nov-2020	Adrienne Walcott	Updated to reflect TM Forum Approved Status
Pre-production	28-May-2021	Alan Pope	Final edits prior toV2.0.0 publication
Production	26-Jul-2021	Adrienne Walcott	Updated to reflect TM Forum Approved Status
Pre-production	26-Nov-2021	Alan Pope	Final edits prior toV2.1.0 publication
Production	21-Jan-2022	Adrienne Walcott	Updated to reflect TM Forum Approved Status
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