TM Forum Introductory Guide

Autonomous Networks – Business requirements & architecture

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Notice

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Executive Summary

This document provides business requirements and business architecture of services and infrastructure supported by autonomous networks, including the user requirements per user stories, key business capabilities and architecture, and related key metrics for measuring autonomous levels, as well as new business models of production, ecosystem, collaboration. Besides, examples of the lifecycle of AN services are illustrated for understanding the usage of business requirements and architecture.

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 architecture for formulating some common services and capabilities of Autonomous Networks. The common Autonomous Network 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 network operations e.g. platform based, dynamic process, flexible production operations

The key requirements of business architecture of Autonomous Networks are as follow:

- The basic business metrics of Autonomous Networks is called “Zero-X” experience, which specify the overall characteristics of Autonomous network services including zero-wait, zero-touch, zero-trouble and zero-friction.
  The measure of autonomous level of AN services 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-loop, autonomous domain, intent driven interaction.
  The simplified infrastructure is the fundament of Autonomous Networks, which implies less layers, less hops in the context of network architecture, less complicated protocols, more automated network management & operations.
  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. 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.

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 mainly serves as the overall skeleton and high level requirements of business architecture. The fast-reiterative approach is used to further the details in the future releases.

Introduction

It is essential to derive a set of general business requirements and offer common business architecture 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.

The ultimate goal of Autonomous Networks is to enable the digital transformation and seamless service experience of vertical industries and consumers through autonomous network/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.

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 architecture 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.

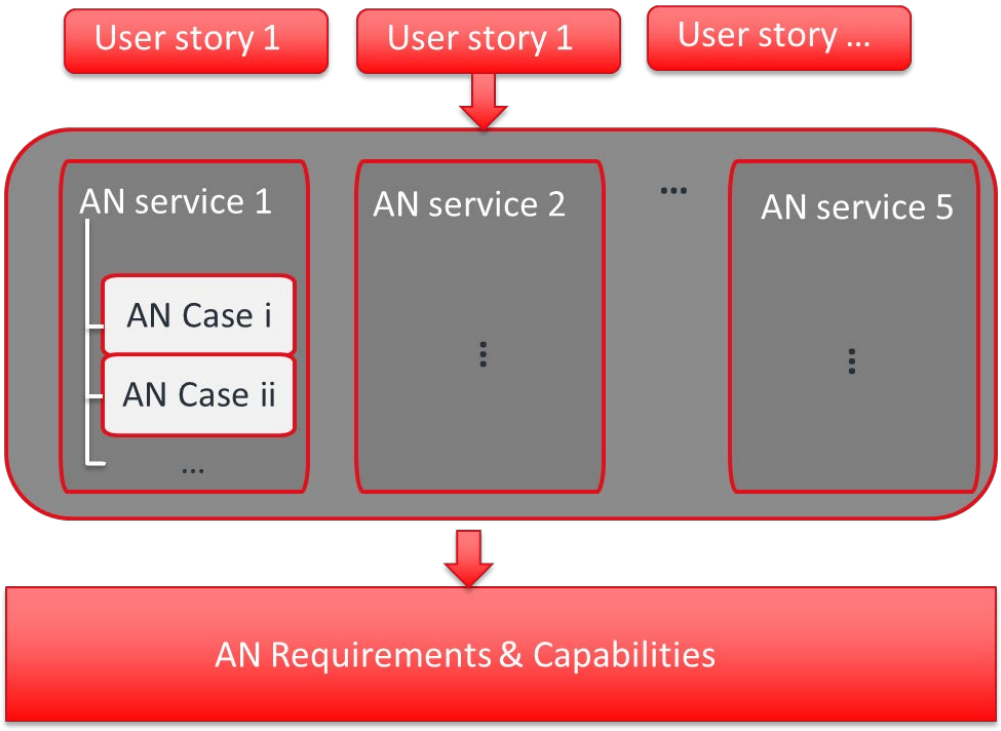
1. Methodology for the development of business requirements and architecture

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 quick-reiterative 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 architecture
- **Quick-reiterative**: illustrate the user scenarios, reference solutions and catalyst project of Autonomous Networks per select AN cases, and refine business requirements and architectures



* AN Cases describes components of lifecycle of AN services

Figure 1. Methodology of Business requirements & capabilities development

The step by step process to develop business requirements and architecture of Autonomous Networks is as follow:

1) **Start with user stories:** collect and describe how the 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 cases:** demarcate and describe key steps/capabilities of full lifecycle of common AN services as AN cases, which maps the AN service to the operation process and Autonomous Networks framework.
4) **Distill common requirements and architecture**: 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 requirement, metrics and capabilities for AN services 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.,…				

2. Business requirements & architecture

2.1 Business vision and model

2.1.1 Business vision

According to the Autonomous Networks Whitepaper [1] 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.

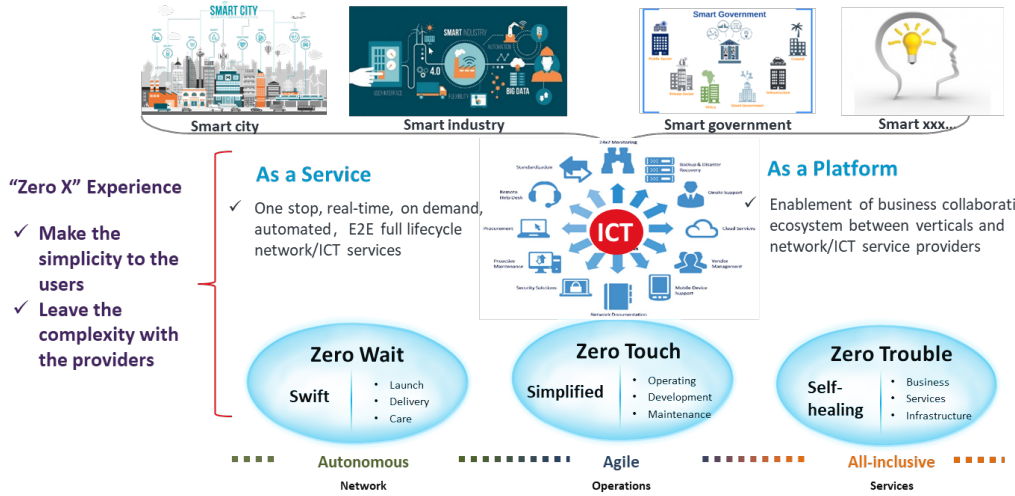


Figure 2. Opportunities to ICT Industry

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:

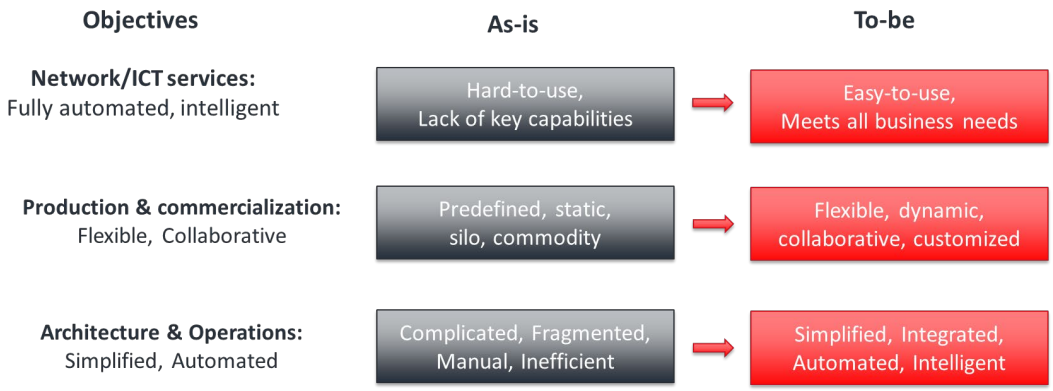


Figure 3. Objectives of Autonomous Networks

As described in the vision document [2], 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:

- Comprise 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

2.1.2 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 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.
- **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.

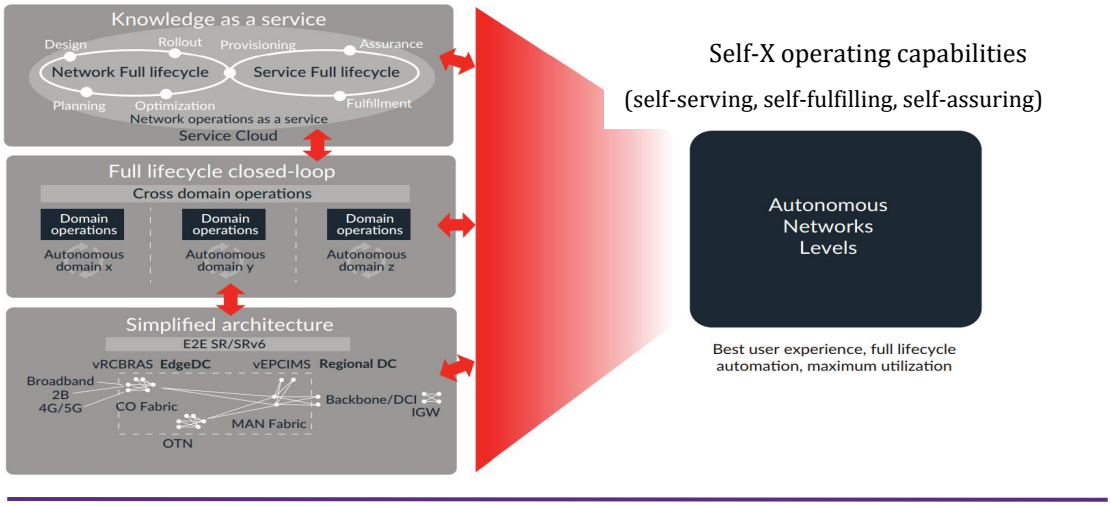


Figure 4. New models enabled by Autonomous Networks

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.

2.2 User story scenarios and AN services

2.2.1 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;

#	Use stories	Example use cases
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, trouble-shooting, 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

2.2.2 Common Autonomous Network/ICT services

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

Table 3. Categories of Autonomous Network services

AN Services	Business Growth (Vertical industries)	Operations Efficiency (Telecom industry)
Services Automation	1. N**etwork services automation** e.g. VPN, SD-WAN, 5G connectivity	4. **Network operations automation** e.g. predefined services and operations

AN Services	Business Growth (Vertical industries)	Operations Efficiency (Telecom industry)
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 network 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 eexisting 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 the Table 4 are mainly for the purpose of reference and illustration. The commercialization and deployments of exact AN services may vary per business disposition of different service providers.

Table 4. Definition of Autonomous Networks services

Business Category	Users stories	AN services	Descriptions	Example AN cases
Business Growth	Vertical industries (enterprise) e.g. smart city, smart manufacture, self-driving	1. N**etwork 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	1. Automated service offering; 2. automated service provisioning; 3. automated service assurance; 4. RPA (Robotic Process Automation) for

Business Category	Users stories	AN services	Descriptions	Example AN cases
	car, Smart Electric Power, SLA for Financial private line		& availability assurance, etc.	full lifecycle of 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 multi partner 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 …

Business Category	Users stories	AN services	Descriptions	Example AN cases
Operations Efficiency	Telecom Marketing, operations and network & IT personnel e.g. One trouble ticket for one network fault, Energy saving, Private line for the financial industry, Home online courses	4. **Pipeline operations automation** e.g. predefined services and operations Automatic network fault root cause analysis, Automatic installation and deployment of 5G base stations, DC Energy saving	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; …
		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;…

2.3 Key requirements of AN services and capabilities

As described in clause 1, through analyzing a collection of user stories, common AN 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 services, 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.).

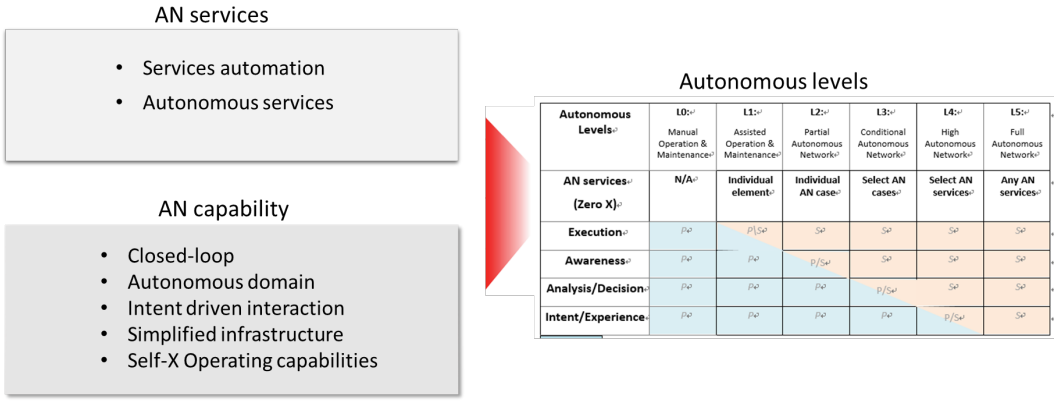


Figure 5. Autonomous levels for AN services and capabilities

2.3.1 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 as the SLA purpose.

Table 7 describes the mapping principle of AN services to autonomous levels from "Zero X" perspective.

It is subject to further development of detailed metrics, characteristics and corresponding measurement of autonomous levels.

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

	Zero wait	Zero touch	Zero trouble	Zero friction
Key user experience	- Launch - Delivery - Care	- Operations - Development - Maintenance	- Infrastructure - Business - Service	-On boarding -Integration?

Table 6. Business characteristics of AN services (SLA)

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

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 reach the consensus on the development of AN capabilities, driving the industry ecosystem to develop according to the roadmap.

The categorization of AN services for autonomous levels is illustrated in Table 7. The basic criteria 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. Autonomous levels of AN services

Autonomous Levels	**L0:** Manual Operation & Maintenance	**L1:** Assisted Operation & Maintenance	**L2:** Partial Autonomous Network	**L3:** Conditional Autonomous Network	**L4:** High Autonomous Network	**L5:** Full Autonomous Network
AN services (Zero X)	**N/A**	**Individual element**	**Individual AN case**	**Select AN cases**	**Select AN services**	**Any AN services**
Execution	*P*	*P\S*	*S*	*S*	*S*	*S*
Awareness	*P*	*P*	*P/S*	*S*	*S*	*S*
Analysis/Decision	*P*	*P*	*P*	*P/S*	*S*	*S*
Intent/Experience	*P*	*P*	*P*	*P*	*P/S*	*S*

: Personnel (manual)

: Systems (autonomous)

- **Level 0 - manual management:** The system delivers assisted monitoring capabilities, which means all dynamic tasks have to be executed manually.
  In Level 0 Zero X business capabilities are not applicable.
- **Level 1 - assisted management:** The system executes a certain repetitive sub-task based on pre-configured to increase execution efficiency.
  In Level 1 Zero X business capabilities are only available to individual element.
- **Level 2 - partial autonomous network:** The system enables closed-loop O&M for certain units based on AI model under certain external environments.
  In Level 2 Zero X business capabilities are available to individual AN case but not be able to be linked up to a AN service.

- **Level 3 - conditional autonomous network:** 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 to enable intent-based closed-loop management.
  In Level 3 Zero X business capabilities are available to select AN cases that are able to be linked up to a AN service.
- **Level 4 - high autonomous network:** 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.
  In Level 4 Zero X business capabilities are available to E2E full lifecycle operations of select AN services.
- **Level 5 - full autonomous network:** 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.
  In Level 5 Zero X business capabilities are available to E2E full lifecycle operations of any AN services.

2.3.2 Key requirements of AN capabilities

Autonomous Networks should support the following capabilities:

Table 8. Key requirements:

Simplified infrastructure	The simplified infrastructure is the fundament of autonomous networks, which implies less layers, less 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.

- Closed loops

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 inter-layer interaction

1) **User closed loop**: the interaction across 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.
   The operations needs 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
3) **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
4) **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

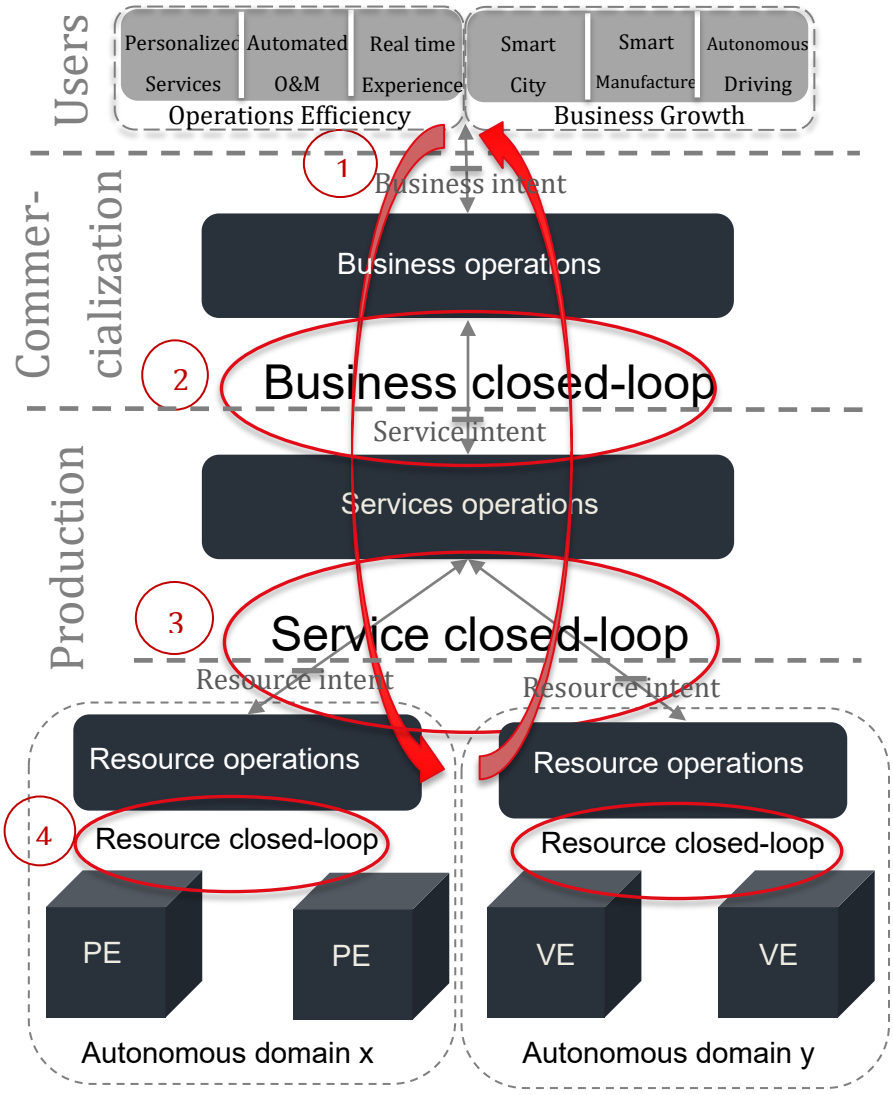


Figure 6. Autonomous Networks closed loops

Figure 6 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 of business/service/resource closed loops 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.

AI in Autonomous Networks

In the Autonomous Networks, AI can be used anywhere as needed. Similar as 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. This will support AI-based automated closed-loop network operations, implement intelligent automation in different service scenarios for meeting autonomous levels of Autonomous Networks.

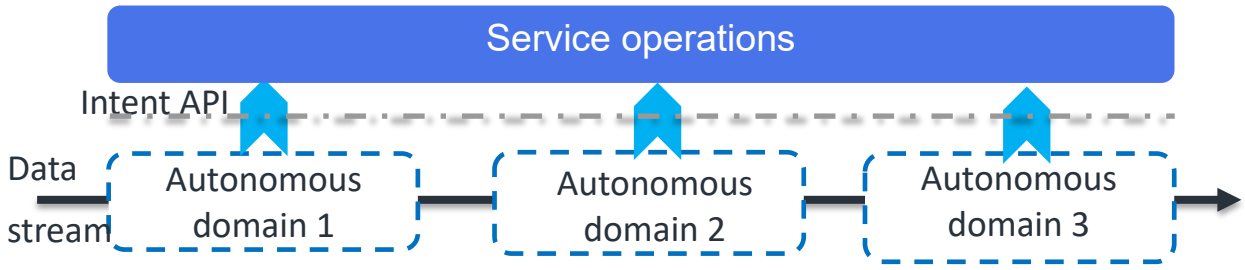
- Autonomous domain requirements:

AN 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.

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
- Collaboration of cross autonomous domain: multiple instances of autonomous domains can be collaborated by upper layers service operations using the intent-based interaction to fulfill the lifecycle of network/ICT services



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.

- Intent driven interaction requirements:

The intent describes the business objective of the users. Traditionally only the professionals can understand network implementation technology, which hinder the service innovation and customer experience. Intent driven interaction is an important bridge between business requirements and network implementation. Transforming business intent into services and related network resource requirements is crucial to achieving business goal. Intent driven networks simplify network management complexity, instead of spending too much time on technical details, which allows the CSP and customers focus on incubating and launching new businesses.

Based on the types of users, it may represent the intents of business/service/resource users.

-Business intent: represents the objective of business users (vertical industry users, consumers etc.), e.g. SLA, Zero X experience

-Service intent: represents the objective of service users (internal owners of business operations), e.g. service attributes (connectivity, bandwidth, availability etc.)

-Resource intent: represents the objective of resource users (internal owners of service operations), e.g. resource attributes (QoS, performance etc.)

- 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. 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 is capable of automated fault analysis, locating, and predictive parameter adjustment, devices can be capable of multi-dimensional 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.

- Self-X Operating capabilities requirements:

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.

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 on demand
	Self-managing: provides the orchestration of business/service/resource intent delivery on demand
	Self-governing: provides the governance of business/service/resource intent delivery on demand
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

3. Examples of lifecycle of AN services

The purpose of this chapter is to illustrate some examples of lifecycle of AN services as depicted in Chapter 2.2.2 Table 3/4, which are mainly used as the examples and references. Per the distinction of the lifecycle of operations, it is classified into two types: service automation and autonomous services.

3.1 Service automation

The following types 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.

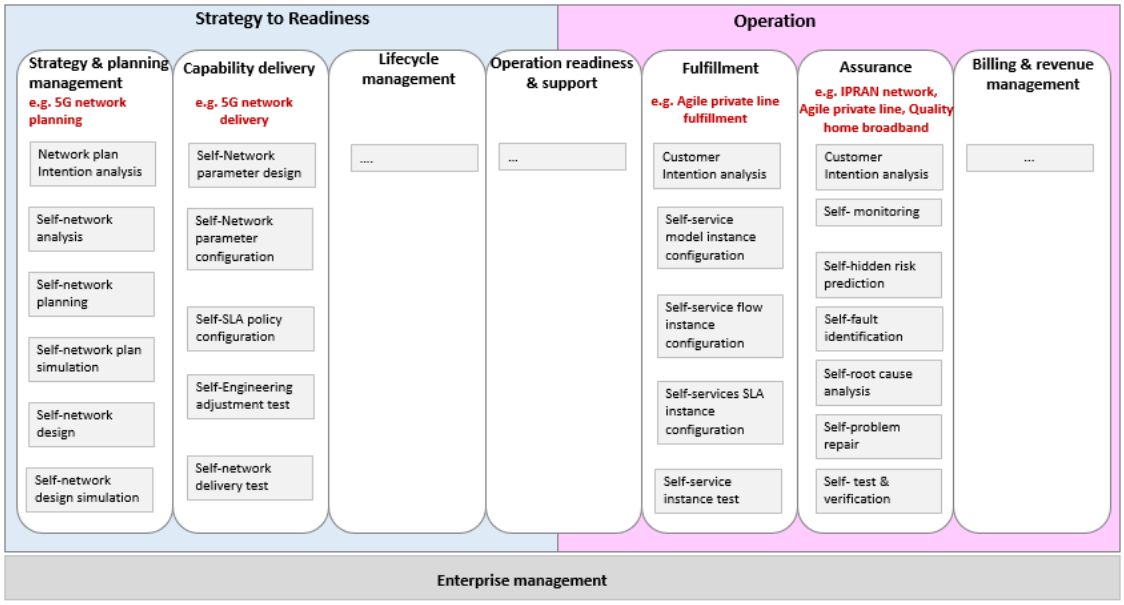


Figure 7. Full lifecycle of existing network services: SIP + Operations

The detail 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.
	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	Customer Intent analysis	The customer's intent input, the system automatically converts

	Automation/intelligence capabilities	Description
e.g. Agile lease line fulfillment	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. 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.
	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.

Appendix I shows some examples of existing network operations automation.

3.2 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 network operations

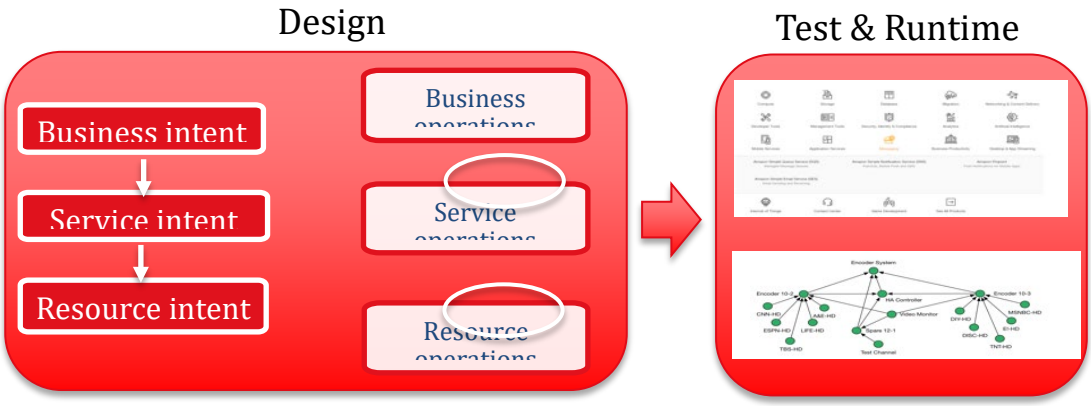


Figure 8. Full lifecycle of innovative autonomous services: design, test & runtime

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

Appendix II shows some examples of innovative autonomous services.

4. Administrative

4.1 References

1. TMF whitepaper (Release 1.0): Autonomous Networks: Empowering Digital Transformation For The Telecoms Industry.
2. TMF IG1193 Cross-Industry Autonomous Networks – Vision and Roadmap.

4.2 Document History

4.2.1 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 of 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

4.2.2 Release History

Release Number	Date Modified	Modified by:	Description of changes
Pre-production	12th July 2020	Alan Pope	Final edits prior to V1.0.0 publication

4.3 Acknowledgments

This document was prepared by the members of the TM Forum Autonomous Networks project:

- Dong Sun (Editor, Futurewei)
- W George Glass (Co-editor, TM Forum)

The following members made some key contributions:

- Hongbo Liu, Rui Wang (China Unicom)
- Xu Wang （Huawei）

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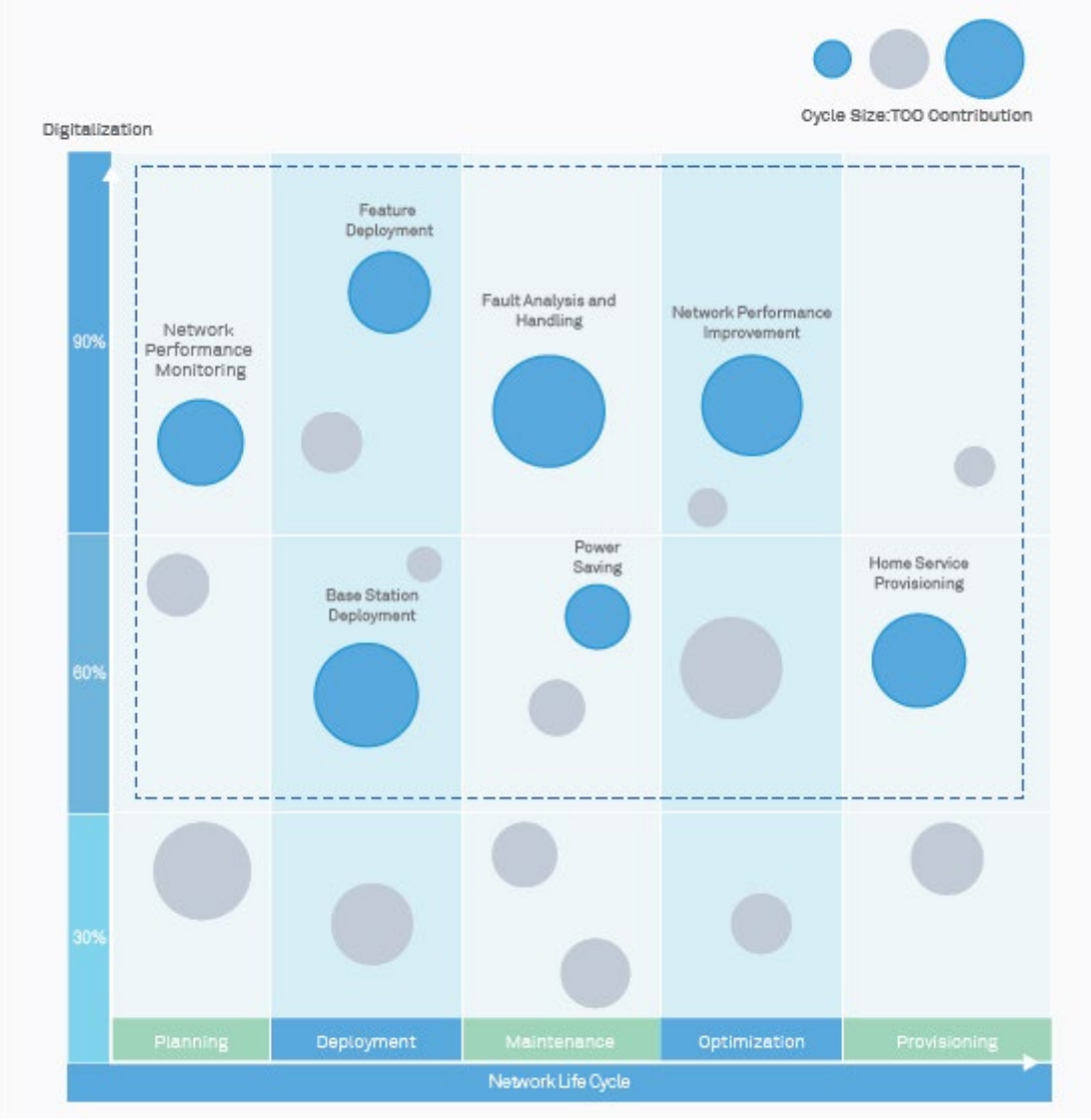
- Ullas Kumar Y (Infosys)
- Vinay Devadatta (Wipro)
- Qiang Cheng (CAICT)

Appendix I: Example user cases of network operations automation

Example of Wireless network operation automation:



Cases of the lifecycle of wireless network operations: planning, deployment, maintenance, optimization, provisioning

Case 1: Base Station Deployment

1) Definition and Description of Scenario

The base station deployment scenario refers to the entire process after site survey, including network planning and design, site design, configuration data preparation, site installation, site commissioning and site acceptance.

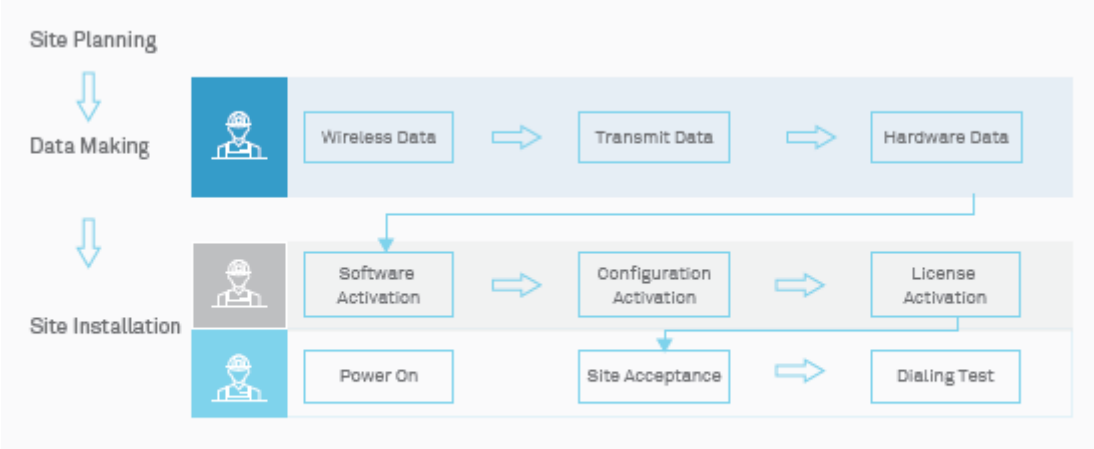


Figure 9. Flow of Base Station Deployment

2) Autonomous level:

Level 1: The O&M tool helps some elements of the process to be automated, but configuration and site acceptance have to be done manually.

Level 2: Some hardware can be detected and configured automatically, and configuration data is simplified based on rules.

Level 3: E2E automation: radio parameter self-planning, hardware self-detection and self-configuration, self-acceptance without dialing test.

Case 2: Network Performance Monitoring

1) Definition and Description of Scenario

The mobile network has entered the stage of very precise planning sites and resources: on the one hand, to identify and forecast high traffic areas, and allocate resources precisely to support business goals; on the other hand, to identify and forecast high-frequency temporary traffic, scheduling resources to meet business objectives.

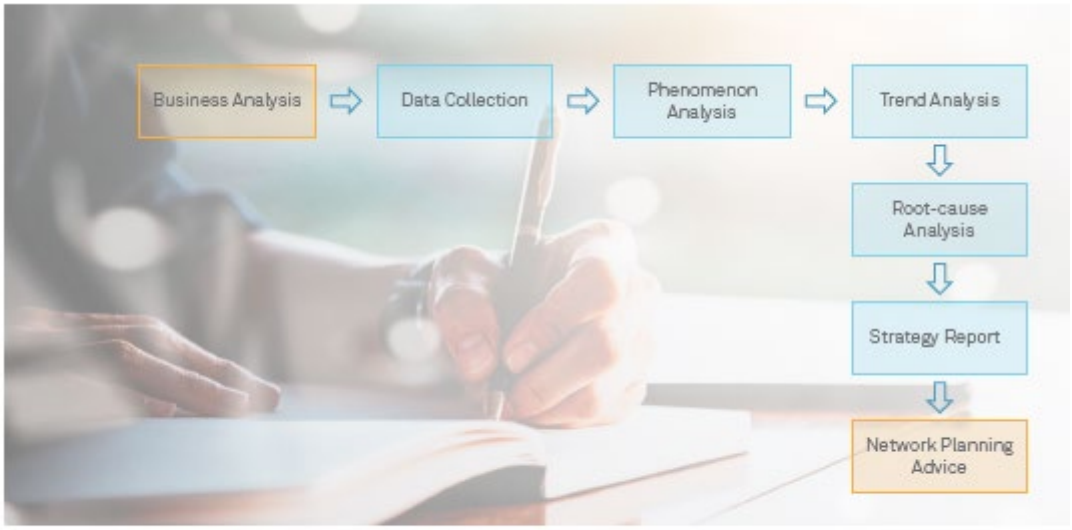


Figure 11. Flow of Network Performance Monitoring

2) Autonomous level

Level 1: Network quality is consistent, and network anomalies can be discovered by tools.

Level 2: 3D presentation of network quality and anomalies, and network planning is self-generated.

Level 3: E2E closed-loop monitoring and planning: predicting network development according to historical network information, finding value areas and hidden problems, recommending the best network planning and estimating the gain automatically.

Case 3: Fault Analysis and Handling

1) Definition and Description of Scenario

The security and reliability is the most important mission of the network, so quick alarm detection and quick fault healing are important. The fault analysis and handling scenario comprises several steps, including alarm monitoring, root cause analysis, and fault remediation.

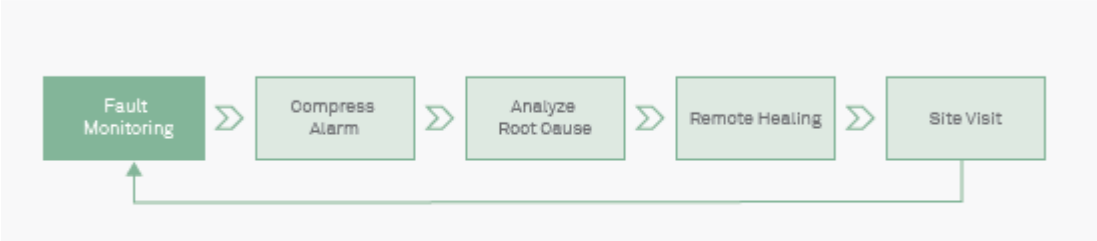


Figure 12. Flow of Fault Analysis and Handling

Monitoring: Real-time monitoring of network alarm, performance, configuration, user experience, and other information.

Analysis: By analyzing the correlation between alarms and other dimensions data, root cause of fault and fault repairing can be achieved quickly.

Healing: Repair fault remotely or by site visiting based on the repairing suggestions.

2) Autonomous level

Level 1: Some tools are used to simplify alarm processing, but thresholds and alarm correlation rules are set manually based on expert experience.

Level 2: Automatic alarm correlation and root cause analysis.

Level 3: Closed-loop of alarms analysis and handling process: Based on the intelligent correlation analysis of multi-dimensional data, accurate location of alarm root cause, precise fault ticket dispatching, and fault self-healing could be reached successfully.

Level 4: Proactive troubleshooting: Based on the trend analysis of alarms, performance, and network data, alarms and faults could be predicted and rectified in advance.

Case 4: Network Performance Improvement

1) Definition and Description of Scenario

Wireless networks are geographically very distributed, and activity varies significantly in different places and at different times of day. This makes the network very dynamic and

complex. That complexity is further increased by the diversity of services and of terminal performance, and by the mobility of users. If the network cannot achieve the benchmark KPIs or SLAs (service level agreements), or enable good user experience, it must be adjusted to meet or exceed those requirements.

This is the function of network performance improvement or optimization.

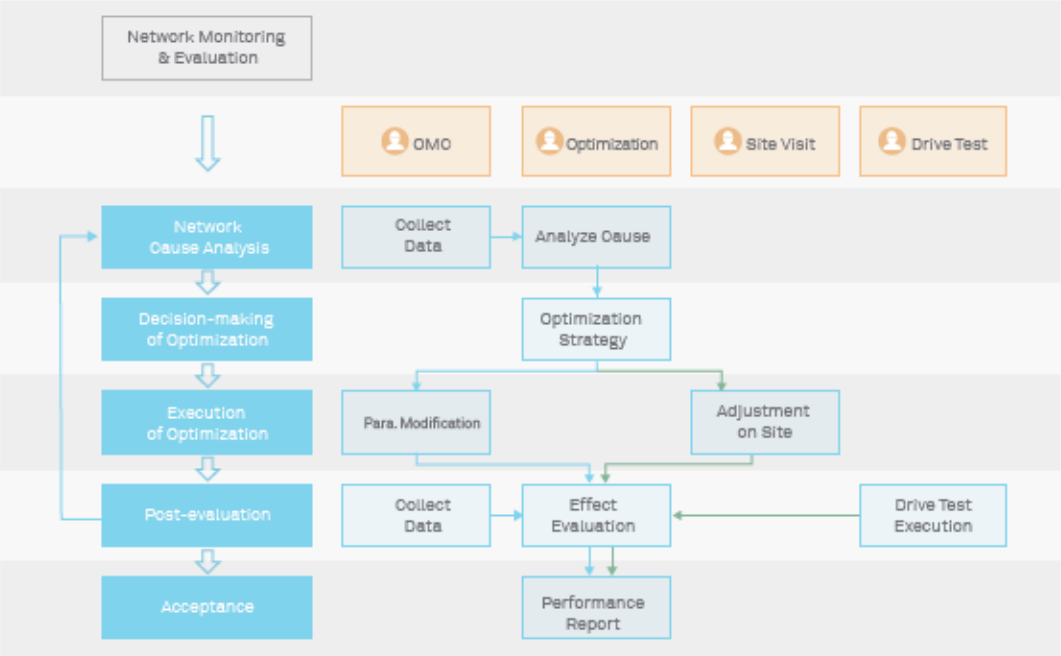


Figure 13. Flow of Network Performance Improvement

The complete process of network performance improvement or optimization includes several stages:

- network monitoring and evaluation
- root cause analysis of performance problems
- optimization analysis and optimization decision-making
- optimization implementation
- post- evaluation and verification

2) Autonomous level

Level 2: Drive test evaluation is not required for coverage optimization. Adjustment suggestions are provided automatically.

Level 3: Closed-loop of network performance improvement:

Automatic identification of network coverage and quality problems, automatic configuration of performance parameters, and automatic evaluation.

Level 4: Dynamic adjustment is implemented based on the scenario awareness and prediction to achieve the optimal network performance. Network prediction capability is available: scenario change trends could be perceived, and network configuration could adjust real-time to achieve optimal performance.

Case 5: Site Power Saving

1) Definition and Description of Scenario

T Site power consumption cost accounts for more than 20% of network OPEX. Although network traffic declines greatly during idle hours, equipment continues to operate, and power consumption does not dynamically adjust to the traffic level, resulting in waste. It is necessary to build the "Zero Bit, Zero Watt" capability.

Figure 15. Flow of Power Saving

2) Autonomous level

Level 2: Tool aided execution.

Level 3: Power-saving closed-loop: Based on the analysis of traffic trends, self-adaptive generation of power-saving strategies, effect and closed-loop KPI feedback.

Level 4: Real-time adjustment of power-saving strategies based on traffic prediction. Through integration with third-party space-time platforms, the operator can also add predictive perception of traffic changes, smooth out the user experience, and maximize power-saving.

Case 6: Wireless Broadband Service Provisioning

1) Definition and Description of Scenario

WTTx has become a foundational service for mobile operators because of its convenient installation and low cost of single bit. Rapid launch of WTTx service, accurate evaluation after launch, and network development planning have become important supports for new business development.

Figure 14. Flow of Home Service Provisioning

2) Autonomous level

Level 1: Blind launch.

Level 2: Automation tools to assist the launch, check the coverage and capacity of the user's location before the business hall, and experience evaluation.

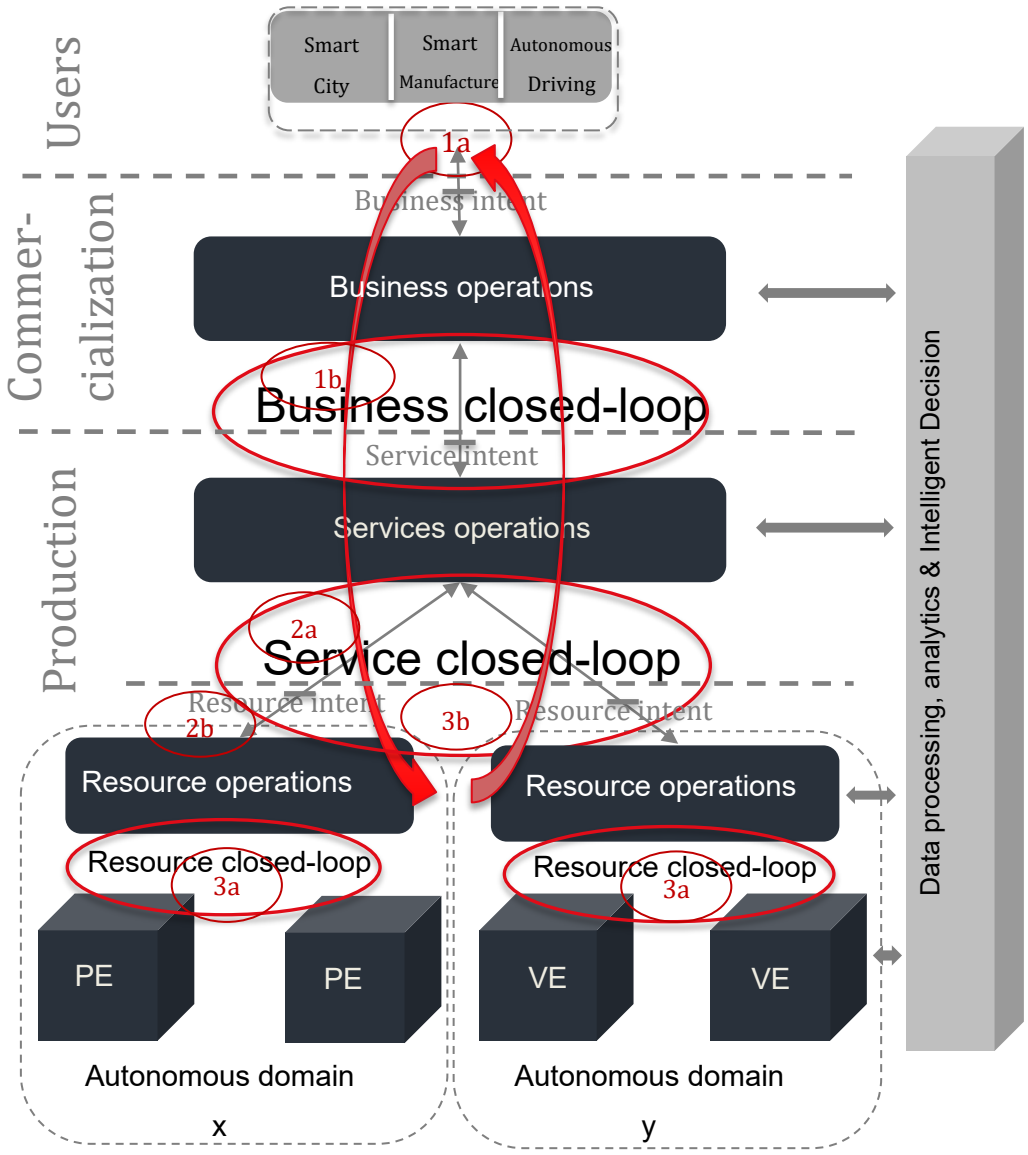
Level 3: Closed-loop for business launch: Integrated with BOSS system to achieve one-step precise launch, remote account launching, CPE installation, fault self-diagnosis and complaint analysis.

Level 4: Auto-balancing of multi-service, automatic value areas identification and network planning recommendation based on network problems forecasting.

Appendix II: Example user cases of autonomous ICT services

Scenario: autonomous ICT services for Smart city/IoT:

Smart city needs autonomous ICT service (AIS) for a real time, on demand, dynamic and always-on automated information transfer, processing and storage.



1) Business closed-loop:

1a) **Business interaction**: the user indicates the business intent to order the autonomous ICT service online e.g. through AI assisted automated voice customer service in "Business

operations (BO)" system, e.g. "I like to order AIS for enabling my smart city (xxx) IoT (xxx) application";

1b) **Business request**: the BO translates the business intent into business SLAs, e.g. connectivity, availability, security & quality of service (e.g. real time, on demand) with the assistance of business intelligence (BPAID), and confirm with "service operations (SO)" system as service intent.

2) Service closed-loop:

2a) **Service interaction**: the SO translates the service intent into resource intent (BW, redundancy/protection/recovery, E2E delay/jitter, etc.) with the assistance of service intelligence (BPAID), and confirm with "resource operations" systems across all autonomous domains

2b) **Service fulfillment**: the "Resource operations (RO)" systems in each autonomous domain to carry out the resource reservation (e.g. BW, computing –cloud/edge) and deploy the applications (e.g. IoT GW, AI engine, caching) to the runtime platform.

3) **Resource closed-loop**:

3a) **Service execution**: Set up the connectivity and launch the applications on demand per service attributes (BW, delay/jitter, availability & security) ; Collect/report the data from various devices (e.g. static/moving meters, camera); transfer the data to the local PoP (edge) for real time info processing (analytics, decision, caching, forwarding etc.)

3b) **Service assurance**: the RO instructs the anchoring points of the infrastructures to monitor and alert the abnormal events (e.g. performance, fault, security attack), and determines the reactions with the assistance of resource intelligence (BPAID) in real time. The RO may report to the SO if the events is beyond the capacity of single autonomous domain level, the SO will take responsibility for cross-autonomous domain events in real time.

Autonomous levels of closed-loops and services:

- **Business/service/resource closed-loops**:

Level 2: one or multiple Self-X operating capabilities supported in one of the steps of one lifecycle of business, service or resource closed loops e.g. self-planning, self-design or self-ordering

Level 3: one or multiple Self-X operating capabilities supported in the 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 operating capabilities supported in the full lifecycle of all closed loops e.g. self-serving, self-fulfilling, and self-assuring if applicable

- **AN services:**

Level 2: all closed-loops of business/service/resource meet the level 2 criteria at least, then AN services offer "Zero X" experience at level 2

Level 3: all closed-loops of business/service/resource meet the level 3 criteria at least, then AN services offer "Zero X" experience at level 3

Level 4: all closed-loops of business/service/resource meet the level 4 criteria at least, then AN services offer "Zero X" experience at level 4