A whitepaper of

Autonomous Networks: Empowering Digital Transformation For The Telecoms Industry

Objective(s): To develop a common understanding and consensus on the autonomous network concept and automation classification for the simplification of telecom network infrastructure, automated & intelligent operations and innovative services.

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1. Objectives

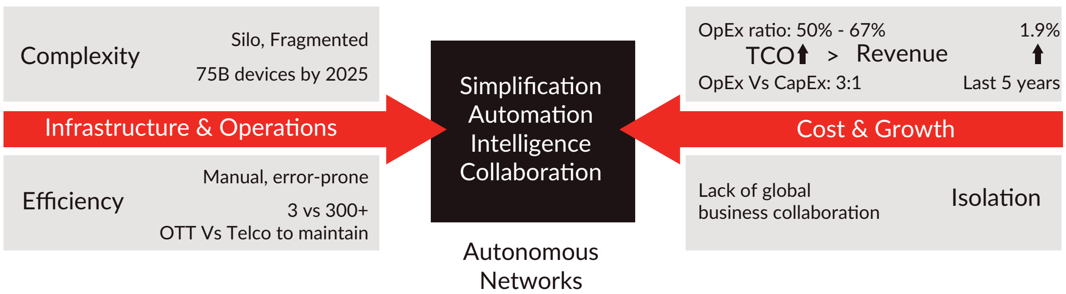
To provide a common industry understanding of autonomous networks including a harmonized classification system and supporting definitions for network automation.

1.1 Challenges and opportunities

Service providers globally are now well underway with their digital transformation with 92.5% of those surveyed for TM Forum's Digital Transformation Tracker saying that they were in the process of their transformation and nearly a quarter (24%) saying that they were "well on the road and reaping significant benefits". Yet the majority (44.5%) were just starting their journey.

But are service providers ready to meet the explosive demand for connecting objects rather than people? According to Huawei's Global Industry Vision (GIV), by 2025 there will be a total of 100 billion connections around the world. Whilst this represents a great opportunity, service providers may find it difficult to meet this demand for hyper-connectivity due to the complexity and fragmentation of their network architecture, deployment and integration, the inefficiency of their operations and a lack of capable knowledge and skills, which are full of legacy technologies, methodologies and tools. Moreover, the legacy mindset of "build and operate" – "first, build the network facility and then think about the operations", implies an ignorance and a lack of respect for the value and importance of operations. Indeed, 5G has the potential to add to this complexity unless service providers embrace automation and simplify their networks, their operations and their management of systems.

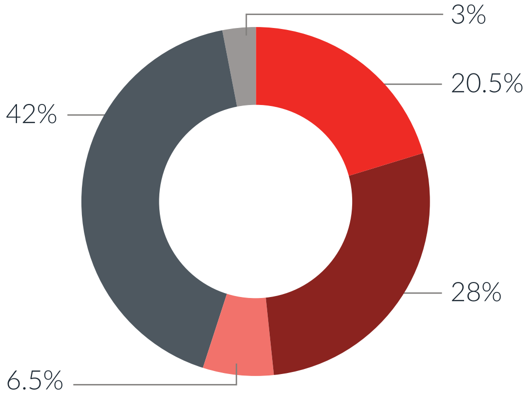
Drivers of Automation



Automation thus needs to be a central pillar in operators' digital transformation strategies. According to a 2018 report by Analysys Mason, 56% of CSPs globally have little or no automation in their networks, but according to their own predictions, almost 80% expect to have automated 40% or more of their network operations, and one-third will have automated over 80% by 2022.

In December 2018, TM Forum surveyed 65 service providers from 37 unique companies as part of its "AI and its pivotal role in transforming operations" report. One of the questions asked was "what is driving automation into operations?" As can be seen in the graphic below, 42% of respondents stated that they would like to introduce new services that require faster and more complicated responses from operations (e.g. on-demand services) than manual processes can provide. A further 28% stated that automation is needed to be able to change processes or settings (e.g. provisioning) more often and more quickly than manual processes allow.

Drivers for introducing automation into operations



- We are introducing new technology (e.g. virtualization) that necessitates operations at speeds not feasibile for manual processes
- We need to change processes or settings (e.g. provisioning) more often and more quickly than manual processes allow
- We have new process requirements that are more complicated and change more often (e.g. partner onboarding for IoT) than manual processes can cope with
- We would like to introduce new services that require faster and more complicated responses from operations (e.g. on-demand services) than manual processes can provide
- Other

TM Forum, 2018

Autonomous networks have real potential and data from the World Economic Forum indicates that network automation could add $9 billion in operating profit from less frequent and shorter network outages.

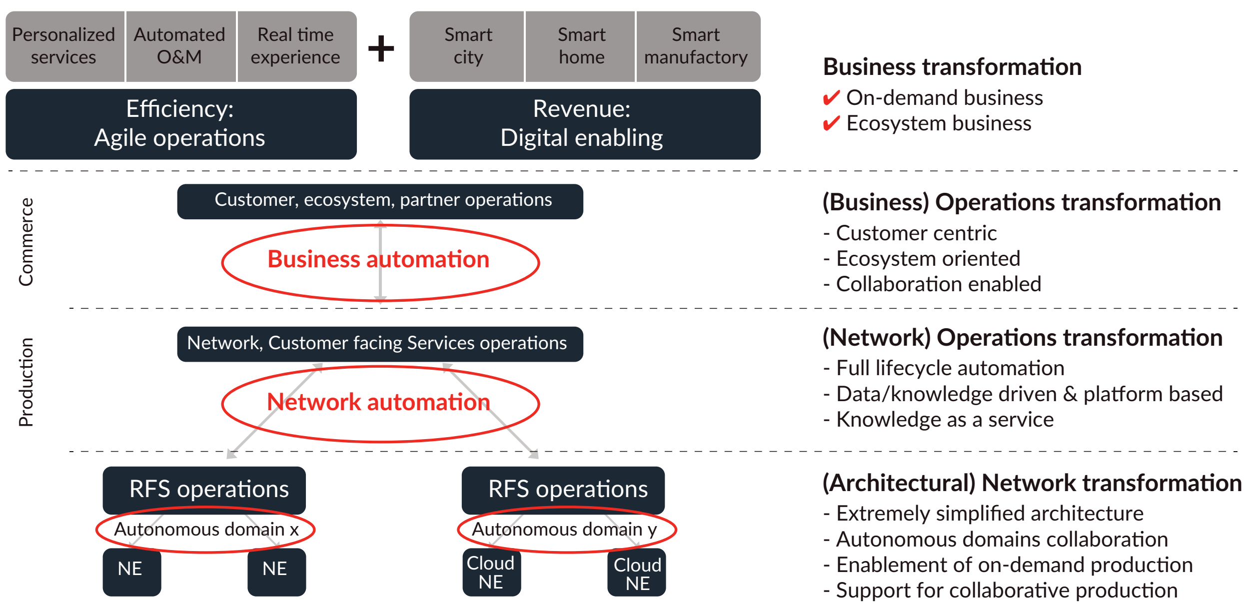
For service providers to really take advantage of the benefits of network automation, especially as part of their digital transformation strategy, they must act quickly to avoid being out-maneuvered by more agile DevOps-driven OTT players and new digital players. Autonomous networks need to take advantage of AI, big data, cloudification and to provide fully automated, self-healing and self-optimizing capabilities which operate right across the stack from resource management to operations and maintenance customer experience and service enablement. For service providers to be successful with their AI and automation strategies, they need to come together with the wider industry ecosystem to build a common understanding of autonomous networks. This should include a harmonized classification system and supporting definitions and levels of automation maturity to enable automation to happen quicker across the telecoms landscape. It would also need to remove the many pain points to allow faster automation and innovation.

2. Autonomous networks: framework and levels

2.1 Framework

To build a more valuable telecoms industry and to take advantage of automation and AI, a simplified network architecture and operations automation are needed for self-configuration, self-healing, self-optimizing and self-evolving telecom network infrastructures. Operators need to offer zero wait, zero touch, zero trouble services, which can provide the best-possible user experience, full lifecycle automation and maximum utilization.

Framework for autonomous networks

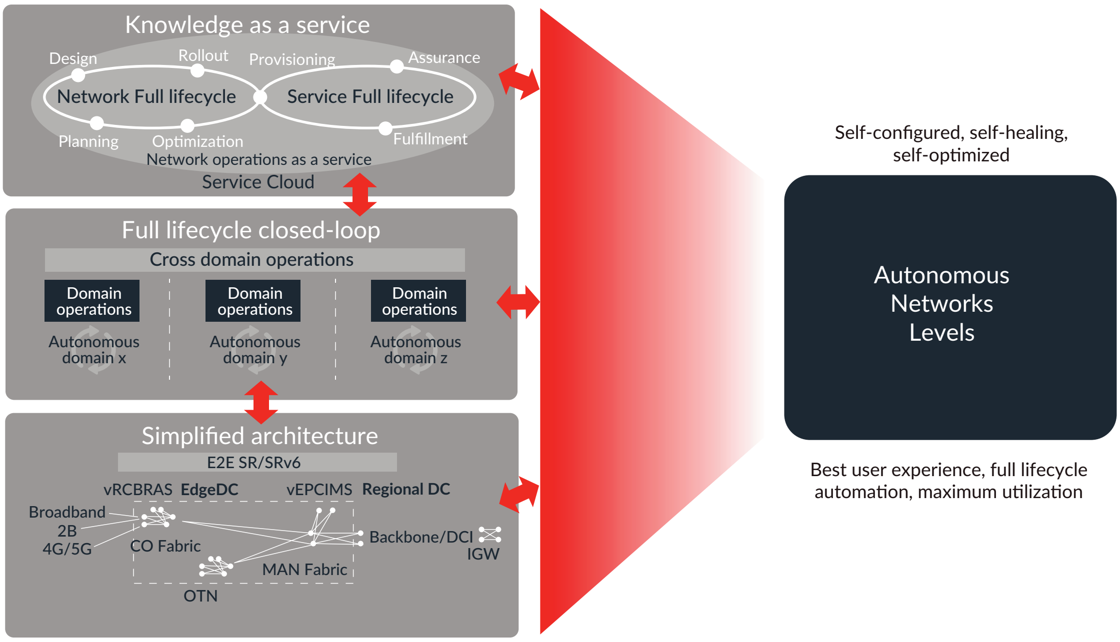


The key of network transformation is to upgrade from fragmented, silo network element interoperability towards a closed loop of network autonomous domain based on an extremely simplified network architecture, which create a foundation for operations automation and to enable on-demand production by means of autonomous domain collaboration.

The key of network operations transformation is to upgrade from legacy customized project-centric approach to a data/knowledge driven platform based on full lifecycle operations automation. The most important part of this transformation 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.

The key of business transformation is to upgrade from isolated marketing to a collaborative, on demand, automated business collaboration and ecosystem. Business automation involves enabling closed loops for customer/business/ ecosystem operations, normally requiring collaboration across multiple service providers globally.

Data & knowledge driven intelligent, simplified networks



In order to measure the maturity and capabilities of autonomy for the simplified architecture, it is important to agree on and to properly define what the different categories or levels such as knowledge-as-a-service and full lifecycle closed loop should be.

2.2 Autonomous networks levels

With the goal of providing a common understanding and consensus for autonomous networks, this whitepaper delivers a harmonized classification system and supporting definitions that:

- Define the concept of autonomous networks
- Identify six levels of network automation from "no automation" to "full automation".
- Base definitions and levels on functional aspects of technology.
- Describe categorical distinctions for a step-wise progression through the levels.
- Educate a wider community by clarifying for each level what role (if any) operators have in performing the dynamic network operations task while a network automation system is engaged.

Autonomous networks levels

Level Definition	L0: Manual Operation & Maintenance	L1: Assisted Operation & Maintenance	L2: Partial Autonomous Network	L3: Conditional Autonomous Network	L4: High Autonomous Network	L5: Full Autonomous Network
Execution	P	P/S	S	S	S	S
Awareness	P	P	P/S	S	S	S
Analysis	P	P	P	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: Personnel, **S:** Systems

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 network:
The system enables closed-loop O&M for certain units based on AI model under certain external environments.

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.

Level 4 - high autonomous network:
Building on L3 capabilities, the system enables, in a more complicated cross-domain environment, analyse and make decision based on predictive or active closed-loop management of service and customer experience-driven networks.

Level 5 - full autonomous network:
This level is the ultimate 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 lower levels can be applied now and deliver immediate cost and agility benefits in certain scenarios. An operators can then evolve to the higher levels, gaining additional benefits and addressing a wider range of scenarios.

Network automation is a long-term objective with step-by-step processes, from providing an alternative to repetitive execution actions, to observing and monitoring the network environment and network device status, making decisions based on multiple factors and policies, and providing effective perception of end-user experience. The system capability also starts from some service scenarios and covers all service scenarios.

This transformation will take several years to fully develop, so we are following an evolutionary process of gradually introducing automation with AI abilities into different domains to bring immediate value.

3. Methodology and examples of application scenarios

3.1 Methodology and use case mapping

Automating the business should be done incrementally over a period of time. It is important to establish operating patterns where traditional operations can co-exist with automation, and where the flow of information does not have to change as more and more processes become automated. One such approach is to empower the DevOps teams to:

- identify the network automation use case discovery
- create the cost and benefit analysis
- prioritize their deployment through the natural product backlog processes
- establish the discipline of determining the information flow of data which informs both automation and non-automated processes to be the same

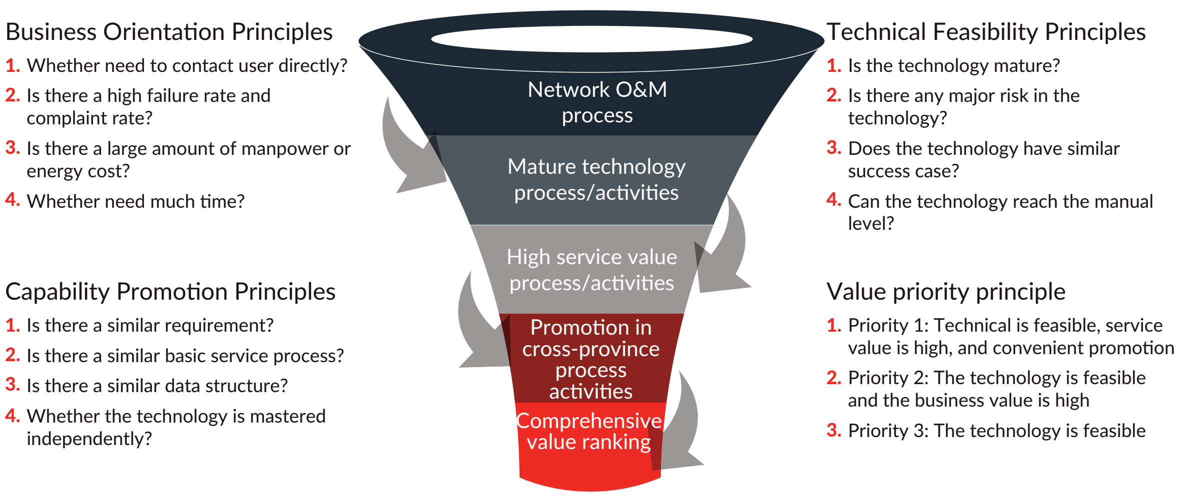
The following two aspects are critical for implementing the network automation design.

a. The need for an arbitration policy in achieving network automation. As processes are automated, the decision rights on how decisions are administered should be data driven and must be applied through policy. The following rules must be well understood and transparent: a) who has decision rights on the policy? B) what are the conditions and resulting actions that must be taken? And, c) where is the policy is applied?

b. The need for an e2e product-service-resource inventory topology view, and its potential patterns. This includes the ability to apply resources when needed whether they are for new business, service restoration, or for healing broken segments. It requires the ability to quickly gain an understanding of the service inventory available, and of whatever prioritization rules that must be in place to apply on these resources.

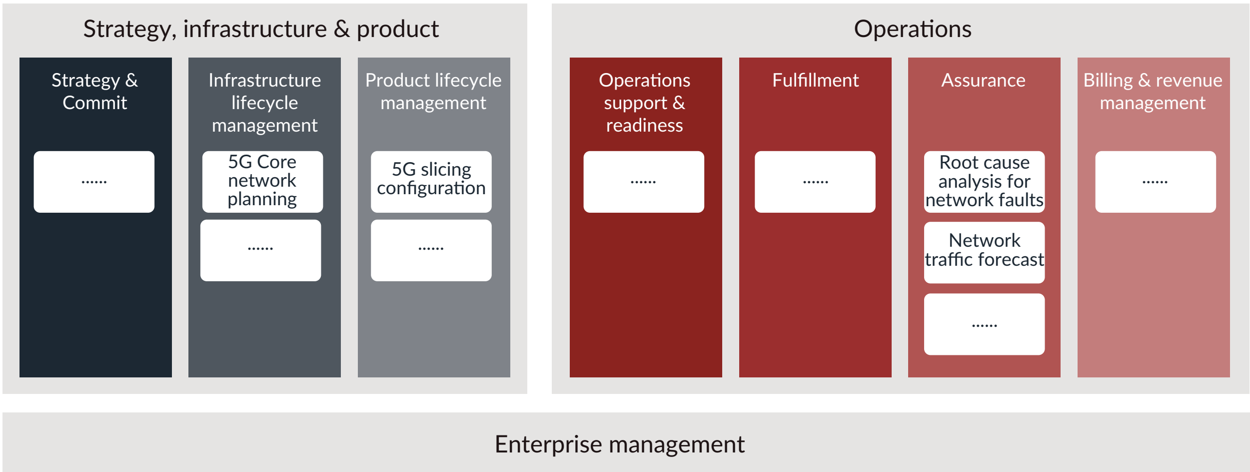
The selection of use cases for autonomous networks can be based on a combination of technical feasibility, business orientation, capability promotion, and value priority, as shown in the following figure.

Funnel of analysis for autonomous networks use cases



In terms of the evolution and deployment of autonomous network use cases, each company can contribute use cases in the context of key functions in the eTOM process framework as the examples.

Mapping of autonomous network use cases



3.1.2 Mapping of autonomous network use cases

Using the eTOM process framework and an automation classification of autonomous networks, to create a funnel analysis and AI technology, we have developed a map of autonomous network use cases as shown in the following table.

Mapping of autonomous network use cases

Level Definition	L0: Manual Operation & Maintenance	L1: Assisted Operation & Maintenance	L2: Partial Autonomous Network	L3: Conditional Autonomous Network	L4: High Autonomous Network	L5: Full Autonomous Network
Typical Features	O&M person manually executes all dynamic tasks.	Automate repeated actions or redundant information elimination based on rules.	Complete network element closed-loop control base on AI models.	Complete awareness, analysis, decision-making and execution closed-loop base on AI system.	External environments awareness to closed-loop O&M across domains with self-learning capabilities.	Experience awareness to closed-loop O&M and learning for cross-industry public ICT infrastructure.
Customer experience journey	Per To-B\To-C business journey and experience measurement metrics					
Operations processes	Based on network planning, construction, network operations & maintenance, optimization, and business operation activities, through AI model training and system optimization to implement process integration and automation					
Networks Capabilities	Existing networks and devices		Telecom AI training platform Hierarchical AI inference module	Network management control , and analysis capability Integrated & wireless backhaul Time and space capability	Converged time and space service Separation of services and networks Network device-and cloud Collaboration	Public ICT Infrastructure

Level Definition		L0: Manual Operation & Maintenance	L1: Assisted Operation & Maintenance	L2: Partial Autonomous Network	L3: Conditional Autonomous Network	L4: High Autonomous Network	L5: Full Autonomous Network
Use Cases	Experience			Intelligent identification of encrypted services	Experience driven wireless optimization Wireless network parameter optimization	Experience driven network optimization	Personal Digital Twins
	Resource		Virtual radio grids	Base Station beam forming Network traffic forecast	Radio resources needed on demand.	Network resource needed on demand	Resource needed on demand
	Energy		Periodic shutdown of the BTS	DC PUE (Water-cooled) Intelligent shutdown of the BTS	Dynamic wireless network power saving per traffic usage	Dynamic DC power saving per environments	Public ICT infrastructure power saving per dynamics of the usage, environments etc.
	O&M	Manual upgrade Manual Cutover Manual recovery of BTS power failure	One trouble one ticket Transmission optical layer commissioning Automated recovery of BTS power failure PON Optical Link trouble Prediction and location	Radio neighboring cell configuration WiFi parameter optimization Core Network changing	Self-recovery of ower faults Feeder fault elimination Fiber fault prediction and locating	Automated cross-Domain Service Provisioning (VPN)	

The Autonomous Network Capabilities Use Cases	Level Definition	L0: Manual Operation & Maintenance	L1: Assisted Operation & Maintenance	L2: Partial Autonomous Network	L3: Conditional Autonomous Network	L4: High Autonomous Network	L5: Full Autonomous Network
	Intent Driven Services	Services take months to provision Services are manually defined Then ordered by customers and then manually designed and then manually provisioned	Services take weeks to provision Services are online ordered but fulfillment process remains largely manual Parts of the fulfillment are automated through static hard coded workflows Only a few service changes are possible online with mostly manual provisioning	Services take days to provision. Services are exposed via an online service catalogue with basic modelling capabilities of services. Customer can interact with catalogue and order service components Services consist of multiple service components and end resources Parts of the service are automatically configured Customer can change some of the service parameters online.	Services take days to provision. Services are ordered online from a catalogue Some level of Intent is used for strategic software defined services Some Services are activated automatically Customer can change many service parameters online via the catalogue and these are automatically provisioned and assured	Services take hours to provision. Services and changes to those services are fully expressed in intent by the customer through a Service catalogue Services are assigned and designed automatically from intent specifications in the catalogue Resources are dynamically created on demand. Intent is translated into automatic network activation, but some aspects remain static with some manual work required (for network physical infrastructure).	Services take minutes to provision. Intent is provided by the customer interacting through Service catalogue APIs and infrastructure is fully intent driven. Auto-generated set of workflow steps based on the intent expressed in the catalogue. Service is automatically provisioned and assured. Network is primarily composed of virtualized infrastructure
	Telemetry and Closed-loop Control	Services take weeks to fix Network is largely composed of distributed systems and has no centralized control	Services take days to fix Centralised control of some of the parts of the network allowing some control capabilities Network is primarily manually repaired, but some repair functions can be remotely performed	Services take hours to fix Automated orchestration Many of the network features are centrally controlled with available interfaces. Some repair functions are automatically performed with zero human intervention. Closed loop control becomes possible with some real time telemetry available	Services take minutes to restore AI and Machine learning driven automation Real-time telemetry working with AI systems providing offline analytics capabilities AI models with analytics provide a framework for closed loop control with some network restore processes being possible. DevOps control of some network aspects	Services take seconds to restore Automated closed loop end2end Large parts of the autonomous network are fully automated with closed loop control happening based on real-time views of telemetry Fully programmable interfaces allow software control of the autonomous network. DevOps fully implemented. Real-time insights on network performance are automatically created and provided to operations – DevOps.	Services never fail Self-optimised, Self-healing network Fully zero touch management The network is fully Autonomous and control systems work in closed loop permanently, with real-time views of the network available. Information is analysed in real-time by AI expert systems and changes happen in split seconds automatically. No manual intervention is required except in extreme circumstances.

3.2 Examples of application scenarios

In the previous section, we outlined the methodology and mapping of use cases selection. Based on these criteria, we have selected the following scenarios for the purpose of illustration and clarification.

3.2.1 O&M Efficiency Improvement

In the O&M domain, O&M practices can be divided into three categories based on how proactive or passive they are. The first category is called Run-to-Failure (R2F). If there is a fault on a network, the O&M personnel immediately go to the site and rectify the fault. This is the lowest level. The second category is called Preventive Maintenance (PvM). With PvM, each device is checked to prevent faults, but efficiency is low. The third category is called Predictable Maintenance (PdM). With PdM, we can calculate the probability that a device will become faulty in the future and then perform targeted maintenance. With PdM, we hope to reduce the workload required for alarm handling and fault locating on telecoms networks by 90%. We also aim to predict the failures and deterioration of 90% of key components, and to achieve network self-healing. In addition, more than 70% of the problems in network faults lie in passive equipment, such as aging or bent optical fibers, and ports that have become loose. In all of these situations, signals change. AI is introduced to learn the characteristics of these changes, to enable operators to predict the changes in advance and to use solutions to solve passive faults. Fault location and prediction for PON optical modules and optical links provides an instructive example of the effect AI can have on O&M practices.

3.2.2 Energy Efficiency Improvement

When it comes to energy efficiency, the number of bits should determine the number of watts. That is, lower traffic volume should result in lower power consumption. In an equipment room or at a site, each system is configured with dozens of parameters. The heat dissipation, environment, and service load models are generated through AI training to maximize the energy consumption efficiency for sunlight, temperature, and auxiliary facilities, such as diesel generators, solar energy devices, and batteries. At the equipment layer, dynamic energy distribution is performed based on service loads. If there is no traffic, power consumption is reduced by using timeslot shutdown, RF deep sleep, and carrier shutdown. In addition, energy consumption of data center hardware, such as server components, can be dynamically reduced. The power consumption of the network system must also be taken into account. The accurate service load prediction model is constructed to balance the traffic on the entire network and achieve the optimal energy consumption efficiency.

3.2.3 Resource Efficiency Improvement

Regarding network resources, on most present-day networks the flow of traffic simply follows the physical topology of the network, and resource usage may be unreasonable. If network scheduling took into account the direction of traffic flow, resource usage efficiency could be greatly improved. At present, however, networks do not have this capability. To address this issue, AI must be introduced, and a traffic prediction model must be created. In this way, precise traffic prediction and the optimal network topology can be provided, and the network paths can be determined by traffic instead of just by physical connections.

3.2.4 User Experience Improvement

Network design, planning, and configuration are automatically performed and the service rollout time can be shortened to one tenth of the original time. For individual users, device and application data is used to achieve optimal user experience based on the automated closed-loop mechanism. For enterprise users, multi-domain global networks can be deployed in minutes with cloud-network synergy enabled, and network-wide routes are automatically advertised and learned, implementing scheduling and routing in ways that are invisible to users. For home users, device-cloud synergy improves home broadband quality and extends experience improvement and problem handling to home networks.

3.2.5 Honoring Customer Commitment

Using the service data to ascertain whether or not we are meeting our customer commitment (SLA), maintain Service Level Objectives (SLO) proactively. From this and other data can discern the level of satisfaction the customer has with the service and what steps we can take to enhance the relationship with the customer.

3.2.6 Working with 3rd party providers

As services are provisioned to customers, some of the components of those products or services are supplied by third parties. Utilizing the same abstraction framework as deployed with Domains, each third party provider can have their elements of the service integrated and automated into the overall service mix. Securing agreement to share telemetry enhances the ability to perform a consolidated closed loop assurance solution improving our customer responsiveness.

Addendum:

Telstra's Network-as-a-service case study
Telstra has gained valuable experience of network automation through its network-as-a-service project. Full details of the project can be found at https://inform.tmforum.org/casestudy/bringing-telstra-naas-life/

To simplify the network Telstra used the approach of carving up the network into a number of different "Network Service Domains" Each domain has a defined set of capabilities it performs. Each Domain must accept a set of responsibilities which enable it to have services "consumed" in an automated way through a standard service catalog. What sits in front of the domain is NaaS (Network as a Service) an abstraction layer which enables any approved entity to request services from those domains using a standardized framework common to all domains.

The network as a Service "NaaS" APIs are important ingredients to design simplified network, closed loop operation and business automation. The NaaS abstraction layer exposes TMF Open APIs for service instance management operations. It facilitates communication between:

1. Network service domains and Digital Apps, BSS/OSS

2. Across multiple Network Service Domains

NaaS allows Digital & IT systems to communicate with network services domains using standardised language and constructs for managing the network services instance lifecycle.

It also facilitates cross network domains interactions for executing various operations including feasibility, provisioning, activation, problem notification, diagnostics and remediation. It also provides a communication mechanism between two or more network service domains for managing composite service instance operations.

Remark:

1. The white paper will be refreshed periodically in the form of new releases per the contributions.
2. In particular, the section of use cases is evolved per further contributions and refinements, for instance, the use cases may be aligned based on the closed loop of network automation, operations automation and business automation.

References:

1. AI maturity model