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GROUP REPORT

Fifth Generation Fixed Network (F5G); Fixed Network Autonomous Network level definition and evaluation

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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) Fifth Generation Fixed Network (F5G).

Modal verbs terminology

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1 Scope

The present document defines the ETSI ISG F5G Autonomous Network features for different ETSI ISG F5G fixed network generations, to provide an evaluation basis for measuring the Autonomous Network level of a fixed network along with its components and workflows. These features include the intelligent characteristics of each Autonomous Network level (from L0 to L5) and the operators' operational management process. The present document also defines the evaluation methodology to score the level of specific systems.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] TM Forum IG1230 (V1.1.1): "Autonomous Networks Technical Architecture".

[i.2] TM Forum IG1218 (V2.2.0): "Autonomous Networks - Business requirements & architecture".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

autonomous network: See the definition of "Autonomous Network" in the Terminology of TM Forum IG1230 [i.1].

closed loop: See the definition of "Closed Loop" in the Terminology of TM Forum IG1230 [i.1].

general task: one of intent translation, awareness, analysis, decision and execution

general workflow: set of general tasks forming a complete closed loop management system from receiving network management and operation requirements to realizing those requirements in the deployed network

operation workflow: one of planning, deployment, fulfilment, maintenance and optimization

operational sub-task: sub-task in an operation workflow

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AI	Artificial Intelligence
API	Application Programming Interface
CPE	Customer Premise Equipment
CPU	Central Processing Unit
DBA	Dynamic Bandwidth Assignment
E-ONU	Edge Optical Network Unit
F5G	Fifth Generation Fixed Network
F5G-A	Fifth Generation Fixed Network Advanced
FTTR	Fibre-To-The-Room
GUI	Graphical User Interface
HQoS	Hierarchical Quality of Service
KPI	Key Performance Indicator
LOF	Loss Of Frame
LOS	Loss Of Signal
NE	Network Element
OA	Optical Amplifier
OCh	Optical Channel
ODN	Optical Distribution Network
OLT	Optical Line Terminal
ONU	Optical Network Unit
OPEX	OPerational EXpenditure
OTN	Optical Transport Network
PON	Passive Optical Network
P-ONU	Primary Optical Network Unit
SDO	Standards Development Organization
SLA	Service Level Agreement

4 General requirements

4.1 Background

The Artificial Intelligence (AI) technology is continuing to develop rapidly, and has been successfully applied in many technical areas, greatly promoting the implementation and application of AI in various industries. At present, the application of AI technology in telecom networks is also being studied by the telecom industry, and related standards are evolving in the related Standards Development Organizations (SDOs).

Once SDN technology was introduced in the optical networks, the optical network management and control technology began to evolve towards being more intelligence orientated. AI technologies make full use of the optical network management data to improve the efficiency of optical network management, control and operation.

Current research focuses mainly on developing technical solutions and algorithms to apply AI in the optical networks. There is insufficient research on providing uniform standards to evaluate how intelligent an optical network is. The present document provides an analysis of the approach and tools used for that purpose.

4.2 Autonomous optical network management, control and operation functions

The core functions of optical network management, control and operation include:

- Network planning
- Network deployment
- Network fulfilment

- Network maintenance
- Network optimization

The key aspects of autonomous management, control and operation of an optical network are:

- Planning: to provide optimal network planning, to improve the utilization of network resources while satisfying the service development requirements.
- Deployment: to automatically and accurately deploy the planned network, and to significantly reduce the deployment time.
- Fulfilment: to automatically provision the optical services, improving users' experiences.
- Maintenance: to identify network faults or risks, and to rectify the faults / eliminate the risks in a timely manner.
- Optimization: to improve the resource utilization and service quality, and to improve the resilience of the optical network.

The present document provides the classification and evaluation of the Autonomous Network levels for the fixed optical network management, control and operation, with the intent to guide the industry in the development of intelligent optical networks. The benefits are:

- Providing the industry with an evaluation consensus basis on measuring the autonomous capability of an optical network (and its components).
- Providing guidance to the industry to develop roadmaps, phased objectives, relevant strategies and plans towards an intelligent optical network.
- Providing decision-making assistance to network operators, vendors and other industry participants in technology choice and product planning on the aspect of network intelligence.

5 Overview of general Autonomous Network level classification

5.1 Overview

The Autonomous Network level classification system provides a common understanding of how intelligent a network is. The most important factors to evaluate the Autonomous Network levels are human participation and systems involvement in the network management, control and operation. The higher the level of Autonomous Network, the fewer are the manual workflows involved.

5.2 General dimensions of Autonomous Network level classification

The Autonomous Network level classification and evaluation involves complex workflows, and therefore needs to be measured by multiple scenarios and dimensions.

TM Forum IG1230 [i.1] defines the general workflow of network management, control and operation, as shown in Figure 7-2 of TM Forum IG1230 [i.1]. The present document uses this general workflow as the key evaluation dimensions for the fixed network Autonomous Network level classification.

In the Autonomous Network level classification system, a general workflow is composed of multiple general task types, which form a complete closed loop management system from receiving network management and operation requirements to realizing those requirements in the deployed network. The autonomy capabilities of the tasks in a general workflow are the most important factors that impact the network autonomy level.

The general workflow of network management, control and operation includes the following five tasks types:

1) Intent translation: As defined in TM Forum IG1230 [i.1], an intent is a formal specification of the expectation, including requirements, goals and constraints, given to a technical system. The intent translation is a set of tasks which convert the operator or customer's intent into detailed management operations and policies, and receive the intent fulfilment feedback results.

2) Awareness: Collecting the raw network data, and pre-processing that data to perceive network information (including network performance, network anomalies, network events, etc.).

EXAMPLE: Pre-processing data such as data cleaning, enhancement, and statistics.

3) Analysis: Analysing the data, which has been collected from the network, in the awareness phase to understand the current network status, predict future trends based on the historical data, and generate operational options that help satisfy network management, control and operation requirements.

4) Decision: Based on the operational options or suggestions provided by the analysis phase, determining the most suitable executable management operations, to satisfy the network management and operation requirements.

5) Execution: Execute the management operations based on the decisions made in the decision phase.

See more detailed description of the general workflow and tasks are defined in TM Forum IG1230 [i.1].

5.3 General method of Autonomous Network level classification

TM Forum IG1230 [i.1] defines the Autonomous Network levels framework (L0 to L5), based on human participation and the systems involved in the general network management workflow. Table 1 is the Autonomous Network Levels Framework based on TM Forum IG1230 [i.1]. In this table, the level evaluation criteria for each type of general tasks are determined by "P", "S" and "P/S", where "P" indicates that the related tasks are performed by humans, "S" indicates that the related tasks are automatically performed by the telecom system, and "P/S" indicates that the related tasks are performed by the cooperation of human and the telecom system.

Table 1: Autonomous Network Levels Framework based on TM Forum IG1230 [i.1]

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	Selected Scenarios				All Scenarios
P: People (manual) and S: Systems (autonomous)						

Based on TM Forum IG1230 [i.1], the detailed definition of each Autonomous Network level (L0 to L5) is following:

- Level 0 - Manual Operation & Maintenance: The system delivers assisted monitoring capabilities, which means all dynamic tasks have to be executed manually.

- Level 1 - Assisted Operation & Maintenance: The system executes a certain repetitive sub-task based on pre-configuration to increase execution efficiency.

- Level 2 - Partial Autonomous Networks: The system enables closed loop O&M for certain units based on the AI model under certain external environments.

- Level 3 - Conditional Autonomous Networks: Building on L2 capabilities, the system with awareness senses real-time environmental changes, and in certain network domains, optimize and adjust itself to the external environment to enable intent-driven closed loop management.

- Level 4 - High Autonomous Networks: Building on L3 capabilities, in more complicated cross-domain environment, the system enables analyse and make decisions based on predictive or active closed loop management of service and customer experience-driven networks.
- Level 5 - Full Autonomous Networks: This level is the end-goal for telecom network evolution. The system possesses closed loop automation capabilities across multiple services, multiple domains, and the entire lifecycle, achieving an autonomous network.

For more detailed description of the general Autonomous Network levels see TM Forum IG1230 [i.1].

5.4 Methodology to define fixed network Autonomous Network levels

The present document uses the above general level definitions as the basis for the fixed network Autonomous Network level classification.

The present document focuses on the Autonomous Network level classifications of the Optical Transport Network and the Access and Residential Networks, which are defined in clauses 7.1 and 7.2 of the present document respectively.

Figure 1 illustrates the methodology used in the present document to define the fixed network Autonomous Network levels.

- Step 1: Identifies the fixed network operation workflows (including the planning and deployment, fulfilment, maintenance, and optimization).
- Step 2: Breaks down each operation workflow into multiple operational sub-tasks.
- Step 3: Maps these operational sub-tasks to different types of general tasks (intent translation, awareness, analysis, decision and execution) in the general workflow.
- Step 4: Defines the detailed Autonomous Network levels for each operational sub-task, based on the level evaluation criteria (i.e. "P", "S" or "P/S") defined in Table 1.

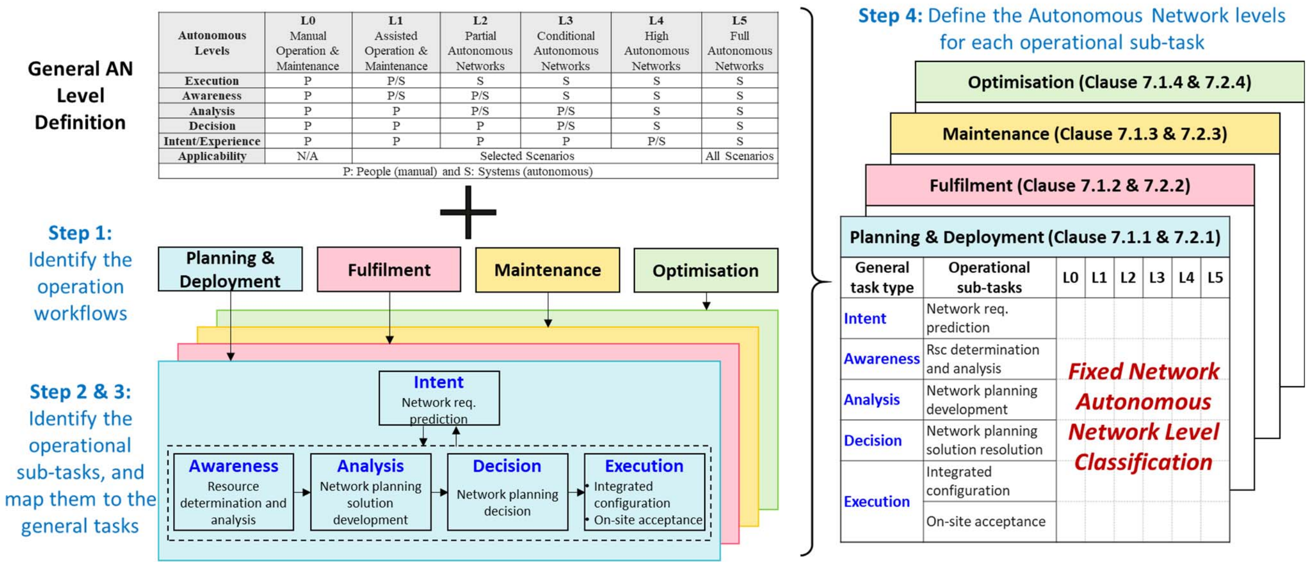

Figure 1: Methodology to define the fixed network Autonomous Network levels

With the Autonomous Network level definition of the fixed networks, the comprehensive score of the Autonomous fixed network levels (L0 to L5) in different scenarios is measured and evaluated. Clause 8 of the present document provides the Autonomous Network evaluation methodology of the fixed networks.

6 Fixed network Autonomous Network architecture and operation processes

6.1 Fixed network Autonomous Network architecture overview

TM Forum IG1218 [i.2] defines the general an Autonomous Network framework, as shown in Figure 6 of TM Forum IG1218 [i.2]. This framework includes three layers and four closed loops. The three layers from top to bottom are:

1) Business operation layer.

2) Service operation layer.

3) Resource operation layer.

The four closed loops, which fulfil the full lifecycle of the interlayer interaction, are:

1) User closed loop.

2) Business closed loop.

3) Service closed loop.

4) Resource closed loop.

Figure 2 shows the fixed network Autonomous Network architecture, which is based on the general Autonomous Networks framework defined in TM Forum IG1218 [i.2]. In this architecture, the network management and control layer corresponds to the Autonomous Network resource operation layer. It contains multiple network management and control systems, each of which is used to manage and control a single self-operating optical autonomous domain, forming a single-domain autonomy. The network orchestration layer corresponds to the Autonomous Network service operation layer, which performs the multi-domain network planning, deployment, fulfilment, maintenance and optimization. The application layer corresponds to the Autonomous Network business operation layer, which provides the business capabilities and the service operation.

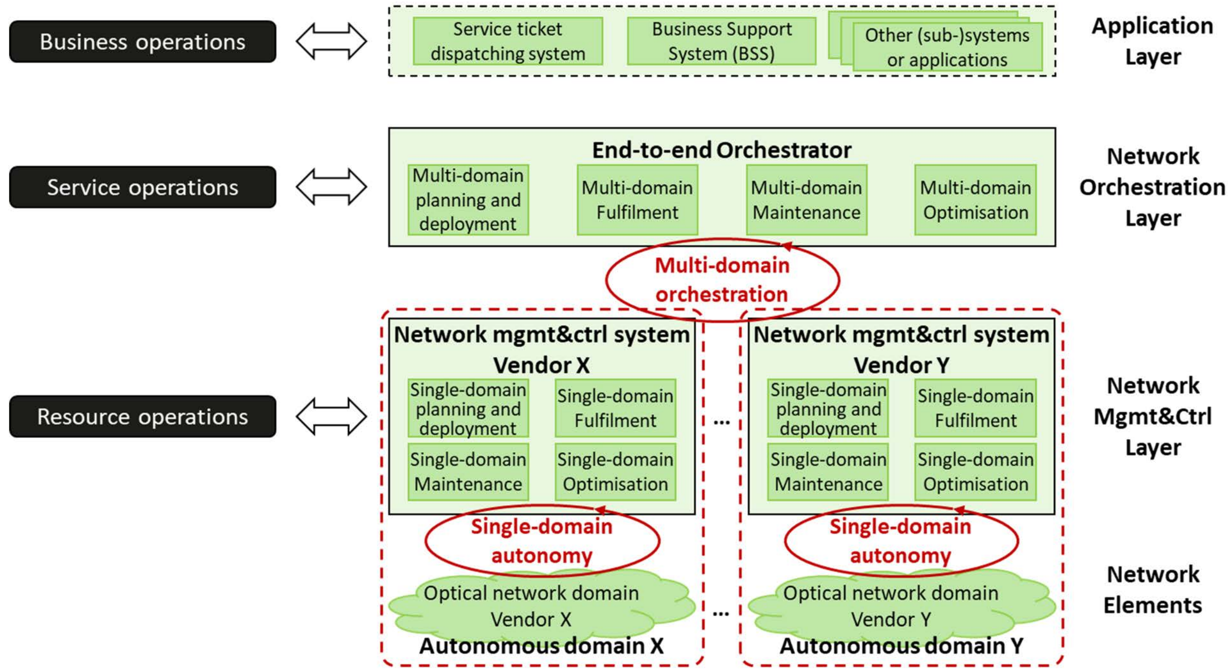

Figure 2: Fixed network Autonomous Network architecture

6.2 Core operation workflows of fixed network Autonomous Network

As described in TM Forum IG1230 [i.1], the full life-cycle of the network management, control and operation is divided into five general operation workflows: planning, deployment, fulfilment, maintenance and optimization. In addition, as a basic function of the network operation, the network resource management is involved in all the above five operation workflows.

Based on the general operation workflows defined in TM Forum IG1230 [i.1], the fixed network core operation workflows are categorized as follows:

- **Planning:**

  The network planning function gains insight into key information such as coverage and high-value user distribution, provides network planning options, and evaluates whether the planned solution satisfies network and service requirements. The core objective of network planning is to have the best utilization of network resources.

- **Deployment:**

  The optical network deployment refers to on-site hardware and software installation and configuration, and the optical performance commissioning based on the result of the network design, as well as the network verification and the on-site acceptance. The core objective of network deployment is to accurately deploy the network in accordance with the network planning. The deployment time should be as short as possible.

NOTE 1: Network planning and deployment are highly related to each other. In clause 7 of the present document, these two operation workflows are put together to define their Autonomous Network Levels.

- **Fulfilment:**

  The procedure for service fulfilment includes receiving user's service provisioning requests, developing and determining the service provisioning solutions, finally configuring and verifying the service in the network.

- **Maintenance:**

  Maintenance refers to network inspection, risk identification and elimination, network status monitoring, and network fault detection, prediction and troubleshooting.

NOTE 2: Network inspection includes network equipment inspection (i.e. checking the equipment information to detect hardware or software risk), and on-site inspection (e.g. inspecting the equipment room and the fibre connections to detect related risks).

NOTE 3: Network fault detection, prediction and troubleshooting includes alarm information gathering, root alarm analysis, root cause analysis, network or service recovery, and fault recovery. Typical examples of optical network faults are: Optical Transport Network (OTN) / Passive Optical Network (PON) equipment fault or link fault, fibre attenuation deterioration, wavelength performance deterioration, and laser or board level hardware error.

- **Optimization:**

  The optimization refers to detecting network quality problems, analysing the root causes, and determining and implementing optimization solutions to meet the requirements of users' service experience and operators' resource utilization.

NOTE 4: Typical network quality problems include performance quality problems (e.g. increased packet delay and packet jitter, intermittent disconnection, packet loss, optical-layer performance deterioration or excessive bit errors), and network resource utilization problems (e.g. unbalanced traffic load, low resource utilization, or suboptimal route problem).

7 Scenario-based fixed network Autonomous Network level classification

7.1 Autonomous Network level classification for Optical Transport Network

7.1.1 Planning and deployment

7.1.1.1 Operational sub-tasks

The planning and deployment operation workflow of the optical transport network is divided into six operational sub-tasks:

- Network requirement prediction
- Resource determination and analysis
- Network planning solution development
- Network planning decision
- Integrated configuration
- On-site acceptance

These six sub-tasks are mapped to the five different general tasks (intent translation, awareness, analysis, decision and execution) in the Autonomous Network general workflow, as shown in Figure 3.

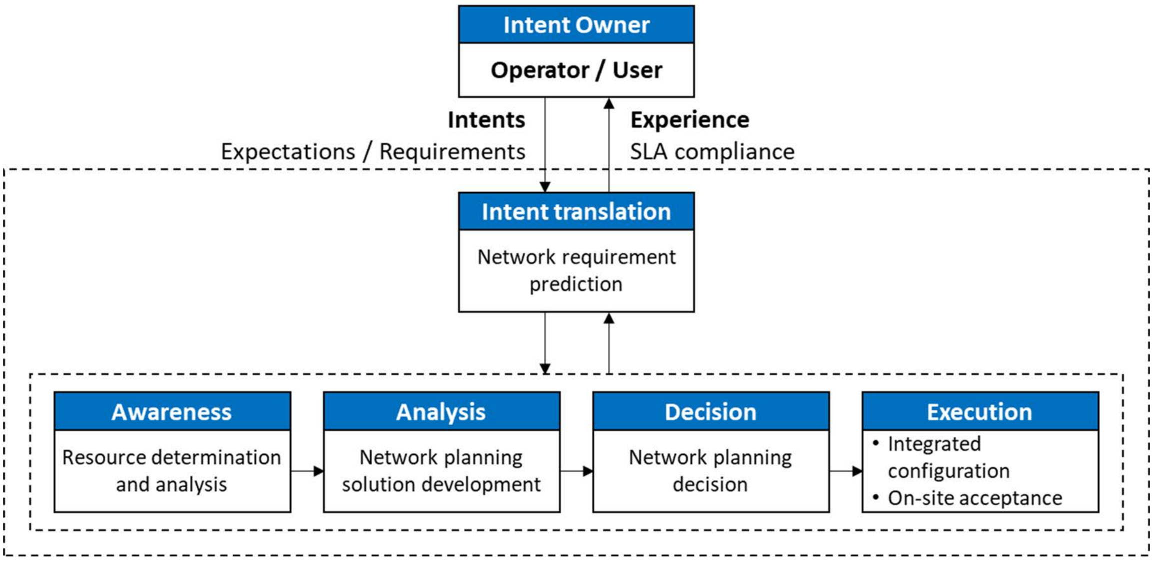

Figure 3: Optical Transport Network planning and deployment operational sub-tasks and their mapping to the general tasks in the Autonomous Network general workflow

- **Intent translation:**
  - **Network requirement prediction:** Output the network planning requirements to the network planner or to the system, based on multiple factors including users' business intentions, network operator's service development objectives and network deployment plans.

EXAMPLE 1: Network planning requirements may be network coverage and capacity requirements, resiliency to name a few.

- **Awareness:**
  - **Resource determination and analysis:** Determine the resource usage of the current network and analyse the gap between the network planning requirements and the current network resource status.
- **Analysis:**
  - **Network planning solution development:** Output the overall network planning result to the network planner (as document) or to the system (in a machine-readable format), based on the network planning requirements and the determination and analysis of the current network resource.
- **Decision:**
  - **Network planning decision:** Based on the outcome of the network planning and the simulation results, evaluate whether the network planning requirements are satisfied.
- **Execution:**
  - **Integrated configuration:** Complete onsite hardware and software installation deployment based on the network planning decision, to ensure that all the Network Elements (NEs) are operating and managed correctly. Complete the initial configuration of the optical network.

EXAMPLE 2: Complete the initial configuration of the optical network e.g. logical fibre connection configuration and optical performance commissioning, to name a few.

  - **On-site acceptance:** Tests and accepts the deployed optical transport network (including the fibre connection, the service connectivity, the optical-layer performance, and the software versions).

EXAMPLE 3: Testing and acceptance of an optical transport network deployment use loopbacks, metering and querying of the network.

7.1.1.2 Autonomous Network level classification

The Autonomous Network level (from L0 to L5) classification for the Optical Transport Network planning and development is determined based on the participation of human and automation systems.

Table 2 describes the Autonomous Network levels for the six operational sub-tasks (network requirement prediction, resource determination and analysis, network planning solution development, network planning decision, integrated configuration, and on-site acceptance) for the Optical Transport Network planning and development.

Table 2: Autonomous Network level classification for the Optical Transport Network planning and development

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Network requirement prediction (Intent translation)	Manually analyse and predict the network requirements.	1. Use auxiliary tools to collect the current status information of the network. 2. Manually analyse and predict the network requirements.	1. The system automatically collects the current status information of the network. 2. Manually analyse and predict the network requirements.	1. The system automatically collects the current status information of the network, and generates preliminary statistics. 2. Manually analyse and predict the network requirements.	1. The system automatically collects the current status information of the network, generates statistics and performs analysis. 2. The system uses intelligent technologies to automatically predict the network requirements. (EXAMPLE 1: service growth trend and resource requirement prediction.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Resource determination and analysis (Awareness)	Manually determine the resource allocation and analysis.	1. Use auxiliary tools to obtain the online physical resource information (active resources). 2. Manually determine the resource allocation and analysis.	1. The system automatically obtains the online physical resource information (active resources). 2. The system automatically generates statistics and performs analysis of the resource usage.	1. The system automatically obtains the online physical resource information (active resources). 2. The system automatically generates statistics and performs analysis of the resource usage. EXAMPLE 2: slots, ports, bandwidth, and wavelength channels. 3. The system automatically analyses the network latency.	In addition to the criteria in L3, the system performs resource prediction and resource bottleneck identification, including resource availability and service availability.	Full-scenario and full-lifecycle automation. The system automatically performs the network requirement prediction, the resource determination and analysis, the network planning solution development and decision, the integrated configuration, and the on-site acceptance. Support automatic online learning and optimization for AI model iteration.
Network planning solution development (Analysis)	Manually develop the planning solution.	Manually develop the planning solution with templates and auxiliary tools. EXAMPLE 3: historical project case library.	The system develops the network planning solution based on fixed rules, assisting with the manual development.	The system automatically develops the greenfield or capacity expansion planning solution, including: (a) service route recommendation (EXAMPLE 4: computed by shortest path or minimum hop number). (b) Optical Channel (OCh) planning (EXAMPLE 5: its centre frequency and spectrum width).	Based on the planning solution, the system further performs service survivability analysis by fault simulation.	
Network planning decision (Decision)	Manually make decisions based on expert experience.	Same criteria as L0.	1. Manually adjust the solution developed by the system. 2. Manually make decisions based on expert experience.	1. Based on the configured rules, the system automatically evaluates the network planning solutions and provides suggestions. 2. Manually make decisions based on expert experience.	The system automatically optimizes the solutions, and determines the optimal solution among the alternatives. EXAMPLE 6: optimal Optical Amplifier (OA) configuration and regenerator locations.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Integrated configuration (Execution)	Manual integrated the configuration.	Manually apply the script on site based on the work order, and manually commission the optical-layer performance.	1. Manual configuration using auxiliary tools and systems. 2. Manually commission the optical-layer performance using auxiliary tools and systems.	1.Automatic configurations of the system. EXAMPLE 7: automatic Customer Premise Equipment (CPE) go-online configuration. 2. The system commissions the optical-layer performance with manual assistance.	1.Automatic configurations by the system. EXAMPLE 8: automatic CPE go-online configuration. 2. The system automatically commissions the optical-layer performance (including the commissioning of the optical paths in wavelength expansion scenario).	
On-site acceptance (Execution)	Manual on-site acceptance.	Manual on-site acceptance based on instruments and tools.	1. The on-site tools automatically perform single-site acceptance. 2. The tools automatically generate an acceptance report.	1. The on-site tools automatically perform site acceptance and transmit the acceptance data back to the system. 2. The system automatically generates the acceptance report.	1. The system automatically exports network performance data and performs network performance acceptance. 2. The system automatically generates an acceptance report.	

7.1.2 Fulfilment

7.1.2.1 Operational sub-tasks

The main fulfilment operation scenario is the service provisioning. The fulfilment operation workflow of the optical transport network is divided into six operational sub-tasks:

- Service provisioning intention analysis
- Resource confirmation
- Service configuration solution development
- Service configuration decision
- Service configuration activation
- Service testing

These six sub-tasks are mapped to the five different general tasks (intent translation, awareness, analysis, decision and execution) in the Autonomous Network general workflow, as shown in Figure 4.

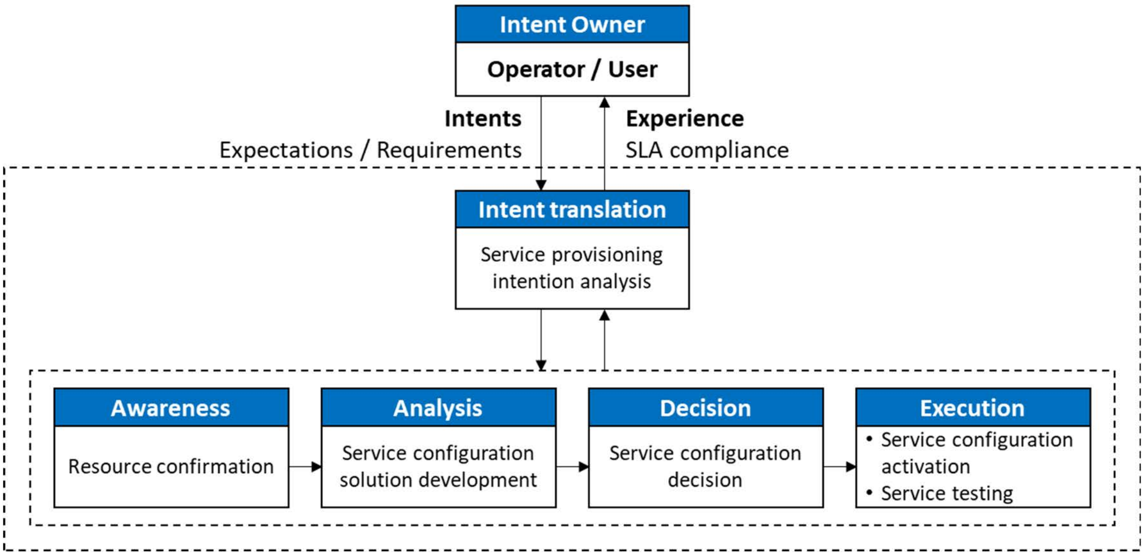

Figure 4: Optical Transport Network fulfilment operational sub-tasks and their mapping to the general tasks in the Autonomous Network general workflow

- **Intent translation:**
  - **Service provisioning intention analysis:** Analyse the service provisioning requirements and translate them into network requirements

EXAMPLE 1: Network requirements such as bearer network type, protection requirements, and Service Level Agreement (SLA) (e.g. latency and bandwidth) assurance policies.

- **Awareness:**
  - **Resource confirmation:** Perform network resource analysis, based on user's service requirements and real-time network status.

EXAMPLE 2: Network resource analysis may include resource status, available ports, link bandwidth, resource usage, and latency.

- **Analysis:**
  - **Service configuration solution development:** Develop the service configuration solutions and emulate the services based on the resource confirmation result.

- **Decision:**
  - **Service configuration decision:** Determine the final service configuration solution, ensuring that the service provisioning requirements are satisfied.

- **Execution:**
  - **Service configuration activation:** Based on the service configuration solution, configure and activate the service on the network (including on-site CPE installation and configuration).
  - **Service testing:** Verify and confirm the service configuration result, including service connectivity and the SLA of the service.

NOTE: If there is not enough resource for the service provisioning, the planning and deployment operational tasks will be implemented to add more resource in the OTN. See clause 7.1.1 of the present document.

7.1.2.2 Autonomous Network level classification

The Autonomous Network level (from L0 to L5) classification for the Optical Transport Network fulfilment is determined based on the participation of human and automation systems.

Table 3 describes the Autonomous Network levels for the six operational sub-tasks (service provisioning intention analysis, resource confirmation, service configuration solution development, service configuration decision, service configuration activation, and service testing) for the Optical Transport Network fulfilment.

Table 3: Autonomous Network level classification for the Optical Transport Network fulfilment

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Service provisioning intention analysis (Intent translation)	Manually analyse the service provisioning order, and translate into network requirements.	Same criteria as L0.	1. Manually analyse the service provisioning order. 2. The system translates the service request into network requirements, based on pre-defined templates.	1. Service order templates are installed in the system in advanced. The system automatically parses the template-based service order, to obtain the service intentions. EXAMPLE 1: source and destination sites and service SLA. 2. The system automatically translates the service intentions into network requirements.	1. The system automatically parses the service order (using the display of the detailed order parsing process), to obtain the service intention. EXAMPLE 2: SLA requirements. 2. The system automatically translates the service intentions into network requirements.	Full-scenario and full-lifecycle automation. The system automatically performs the service provisioning intention analysis, the resource confirmation, service configuration solution development and decision, the service configuration activation, and the service testing. Support the automatic online learning and optimization for AI model iteration.
Resource confirmation (Awareness)	Manually confirm the resources.	Manually use the work orders to record the resources, and manually confirm the resources.	1. The system provides the network resource information. 2. Manually perform the resource statistics and confirmation.	1. The system performs the resource statistics and confirmation. EXAMPLE 3: physical ports, slots, wavelengths, and link availability. 2. Manually perform the final resource confirmation for the service.	The system automatically confirms the network resources based on the service requirements, and provides resource confirmation results, including whether the resources are sufficient to satisfy the SLAs. EXAMPLE 4: latency, bandwidth, and the availability.	
Service configuration solution development (Analysis)	Manually generates the electrical layer and optical layer configuration solutions.	Same criteria as L0.	1. The system supports the electrical layer routing solution development. 2. The optical layer was statically configured in advance.	1. The system supports the electrical layer routing solution development, the generation of multiple alternative solutions, and the simulation of each solution. 2. The optical layer was statically configured in advance.	The system supports the multi-factor optimal routing solution development for multi-layer (electrical and optical layers) networks, and supports the simulation of the solutions.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Service configuration decision (Decision)	Manually determine the electrical layer and the optical layer configuration solution.	Same criteria as L0.	Manually make solution decisions based on the multiple routing solutions generated by the system.	Manually make solution decisions based on the multiple routing solutions and the simulation results provided by the system.	Based on the multiple routing solutions and the simulation results, the system determines the optimal routing solution. EXAMPLE 5: lowest delay or highest resource utilization.	
Service configuration activation (Execution)	Manual configuration.	Manual configuration with auxiliary tools.	1. The system supports the automatic configuration for each single OTN site separately. 2. The system support the automatic configuration of the CPE after it goes online.	1. The system supports the automatic E2E configuration delivery at the network level. 2. The CPEs go online automatically (meaning, once the CPE is powered on, the system automatically performs the CPE initial configuration to put it online). Once the CPE goes online, the services are automatically configured on the CPE.	1. The system supports the automatic configuration of the cross-layer routes, including the electrical and optical layer service configuration and activation. 2. Same criteria as step 2 of L3.	
Service testing (Execution)	Manually use tools to perform service tests.	Same as L0.	1. Manually operate the online system to test the service connectivity. 2. Manually use tools to test the service SLA compliance.	1. Manually trigger the system to perform the service connectivity test automatically. 2. Manually operate the online system to test the service SLA compliance.	Once the service is configured and activated, the system automatically triggers service tests, including the tests of the service connectivity and SLA compliance.	

7.1.3 Maintenance

7.1.3.1 Operational sub-tasks

The most important operational task for maintenance is OTN monitoring and troubleshooting. It includes the following eight operational sub-tasks:

- Maintenance intent
- Network status collection
- Fault identification
- Potential risk identification
- Root cause analysis and location
- Fault / potential risk resolution development

- Fault / potential risk resolution decision
- Fault / potential risk handling and service verification

These eight operational sub-tasks are mapped to the five different types of general tasks (intent translation, awareness, analysis, decision and execution) in the Autonomous Network general workflow, as shown in Figure 5.

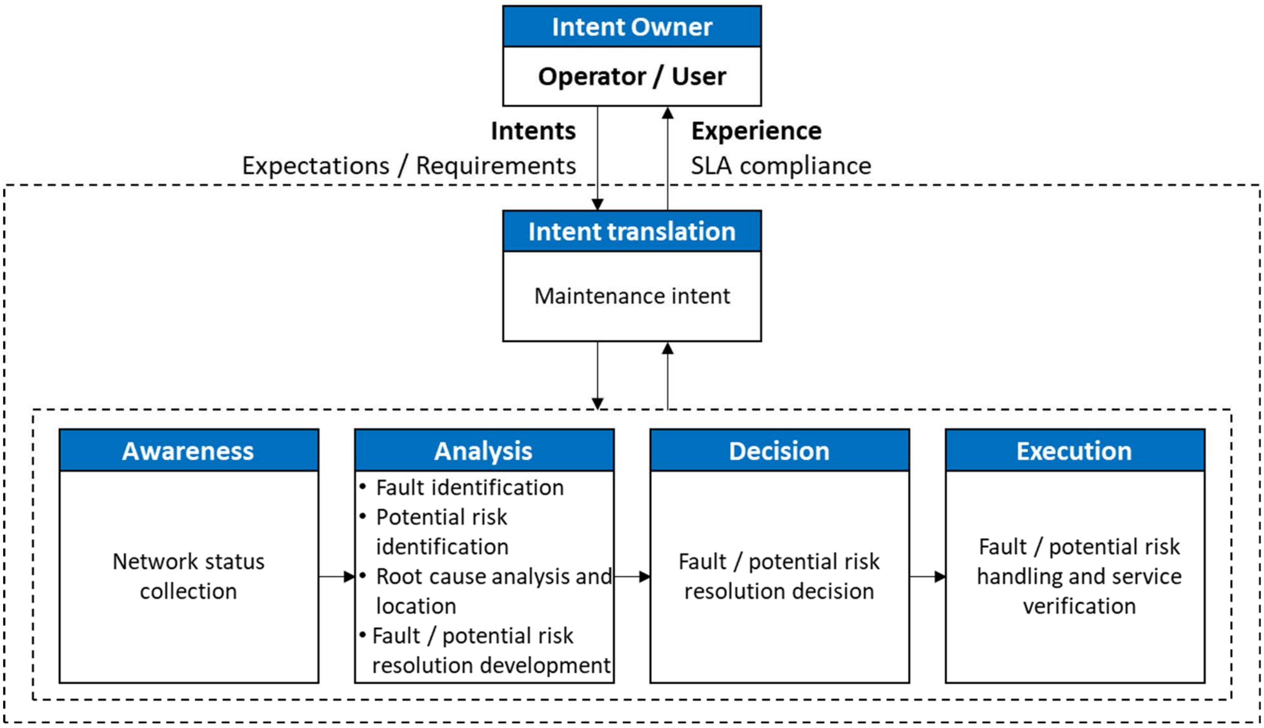

Figure 5: Optical Transport Network maintenance operational sub-tasks and their mapping to the general tasks in the Autonomous Network general workflow

- **Intent translation:**
  - **Maintenance intent:** Based on the network maintenance objectives, determine the network and service monitoring requirements, including the extent of the monitoring requirements, the network reliability requirements, and the service SLA requirements.
- **Awareness:**
  - **Network status collection:** Monitor and collect various status data (including alarms and performance data) for both the networks and services, based on monitoring requirements.
- **Analysis:**
  - **Fault identification:** Analyse and identify the network and service faults, based on the collected network and service status data.
  - **Potential risk identification:** Analyse and discover any potential risks in the network and risk to services in advance of faults occurring, based on the collected performance data for the network and services.
  - **Root cause analysis and location:** Perform correlation analysis on the network based on the identified faults and potential identified risks, identify the root alarms if appropriate, and accurately demarcate and locate the faults.

EXAMPLE: Determine the fibre fault location, the optical power deterioration location, incorrectly configured NEs, faulty hardware, classify fault types, and fault causes.

  - **Fault / potential risk resolution development:** Develop the maintenance solution based on the detected faults and potential identified risks, and the root cause.

- **Decision:**
    - **Fault / potential risk resolution decision:** Determine the network and service recovery solutions and/or potential identified risk elimination solutions, based on the developed maintenance solutions.
- **Execution:**
    - **Fault / potential risk handling and service verification:** Execute the rectification solution based on the decision, and verify the execution result, including the service connectivity and SLA compliance.

7.1.3.2 Autonomous Network level classification

The Autonomous Network level (from L0 to L5) classification for the Optical Transport Network maintenance is determined based on the participation of human and automation systems.

Table 4 describes the Autonomous Network levels for the eight operational sub-tasks (maintenance intent, network status collection, fault identification, potential risk identification, root cause analysis and location, fault / potential risk resolution development, fault / potential risk resolution decision, and fault / potential risk handling and service verification) for the Optical Transport Network maintenance.

Table 4: Autonomous Network level classification for the Optical Transport Network maintenance

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Maintenance intent (Intent translation)	Manually specify the monitored area, scope and specific network monitoring operations.	Manually translate the network monitoring requirements into specific network monitoring operations.	1. Manually configure the monitoring requirements on the system, based on the pre-installed monitoring templates. 2. The system automatically translates the monitoring requirements into the monitoring operations.	1. Manually configure the dynamic monitoring rules on the system. 2. The system automatically performs different network monitoring operations in different situations, based on the configured rules.	1. Manually specify the monitoring area and scope. 2. The system automatically translates the monitoring requirements into detailed monitoring rules, and automatically applies the rules.	Full-scenario and full-lifecycle automation. The system automatically performs maintenance intent, network status collection, fault identification, potential risk identification, root cause analysis and location, fault / potential risk resolution development, resolution decision, handling and service verification. Support the automatic online learning and optimization for AI model iteration.
Network status collection (Awareness)	Manually collect the network status from each NE.	Manually use tools to perform preventive maintenance inspection periodically to collect network status from each NE.	1. The system automatically collects network status information (EXAMPLE 1: alarm data). 2. Each NE collects performance data every 15 minutes or every 24 hours, and uploads the collected data to the management and control system.	1. The system automatically collects network status information (EXAMPLE 2: alarm data). 2. Each NE collects performance data for every 15 minutes or every 24 hours. The system configures the collection rules to collect the required data.	1. The system automatically collects network status information (EXAMPLE 3: alarm data). 2. Each NE collects performance data per seconds or per milliseconds, performs data pre-processing, and uploads the processed data to the management and control system in minutes.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Fault identification (Analysis)	Manually identify the faults, triggered by user complaints.	1. Manually use tools to perform preventive maintenance inspection periodically. 2. Manually analyse the preventive maintenance inspection results to identify potential faults.	1. The system automatically collects alarm data and identifies potential faults. 2. Manually analyse the impact on the services caused by the faults or potential faults.	The system automatically analyses the alarm data based on the configuration rules (EXAMPLE 4: alarm correlation rules), and identifies the affected services.	Based on the intelligent technologies, the system automatically analyses the alarms or potential alarms to identify root cause of the alarms, identifies the affected services, and determines the service status (EXAMPLE 5: interrupted, degraded, or normal).	
Potential risk identification (Analysis)	Manually perform potential risk detection, triggered by user complaints (only for those potential risks that affect users' experience. Other risks will not be identified in Level 0).	1. Manually use tools to perform preventive maintenance inspection periodically. 2. Manually analyse the preventive maintenance inspection results to detect potential risks.	The system automatically identifies potential risks based on configured rules. EXAMPLE 6: an exception will be reported if a certain Key Performance Indicator (KPI) exceeds a static threshold.	The system automatically reports potential risk warnings based on configuration rules (EXAMPLE 7: dynamic KPI thresholds), and automatically identifies affected services.	The system uses intelligent technologies to associate multi-dimensional data, and to identify potential risk events. EXAMPLE 8: optical performance deterioration.	
Root cause analysis and location (Analysis)	1. Manually use tools to access each NE onsite, to query related information and perform correlation analysis. 2. Manually perform fault demarcation and location.	1. Manually use tools to collect current or historical alarm information, performance data and logs. 2. Manually perform correlation analysis, fault demarcation and location.	The system provides related functions to assist with manual fault demarcation and location. EXAMPLE 9: showing the alarms and logs associated with the service path graphically.	The system automatically performs correlation analysis based on the configuration rules (EXAMPLE 10: alarm correlation rules), and provides possible root causes, facilitating manual fault demarcation and locating.	The system supports precise demarcation and location of faults and potential risks. EXAMPLE 11: equipment hardware fault location, or fibre or wavelength interruption / deterioration location.	
Fault / potential risk resolution development (Analysis)	Manually analyse the impact based on the root alarm.	Manually use the system to collect related information, to analyse the root cause, and develop the maintenance solution.	The system provides recovery suggestions based on the manual fault demarcation and location.	The system provides rectification suggestions for the faults or potential risks, based on the configuration rules.	The system automatically provides fault / potential risk resolutions, based on the accurate demarcation and location of faults or potential risks.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Fault / potential risk resolution decision (Decision)	Manually determine the fault / potential risk resolution.	Manually use the system to collect related information, analyse the root cause, develop and determine the fault / potential risk resolution.	Manually determine the fault / potential risk resolution based on the system suggestions.	The system provides the recommended fault / potential risk resolution, enabling manual decision-making.	The system automatically performs evaluation and determination of the fault / potential risk resolution, by using network and service simulation.	
Fault / potential risk handling and service verification (Execution)	1. Manually execute the repair operation. 2. Manually verify if the affected services have been recovered from the fault / potential risk.	1. Manually use tools to execute the repair solution step by step. 2. Manually use tools to verify if the affected services have been recovered from the fault / potential risk.	1. Manually trigger the system to automatically execute the repair solution. 2. Manually trigger the system to verify if the affected services have been recovered from the fault / potential risk.	1. Manually trigger the system to automatically execute the repair solution. 2. The system automatically verifies if the affected services have been recovered from the fault / potential risk.	1. The system automatically triggers the execution of the fault / potential risk handling solution, based on the decision it made. 2. The system automatically verifies if the affected services have been recovered from the fault / potential risk.	

7.1.4 Optimization

7.1.4.1 Operational sub-tasks

The main purpose of network optimization is to improve the network quality, including the improvements of resource utilization, service quality and energy efficiency.

The optimization operation workflow for the optical transport network is divided into seven operational sub-tasks:

- Optimization intent
- Quality monitoring
- Quality analysis
- Poor / sub-optimized quality root cause analysis
- Quality optimization solution development
- Quality optimization decision
- Quality optimization and verification

These seven sub-tasks are mapped to the five different types of general tasks (intent translation, awareness, analysis, decision and execution) in the Autonomous Network general workflow, as shown in Figure 6.

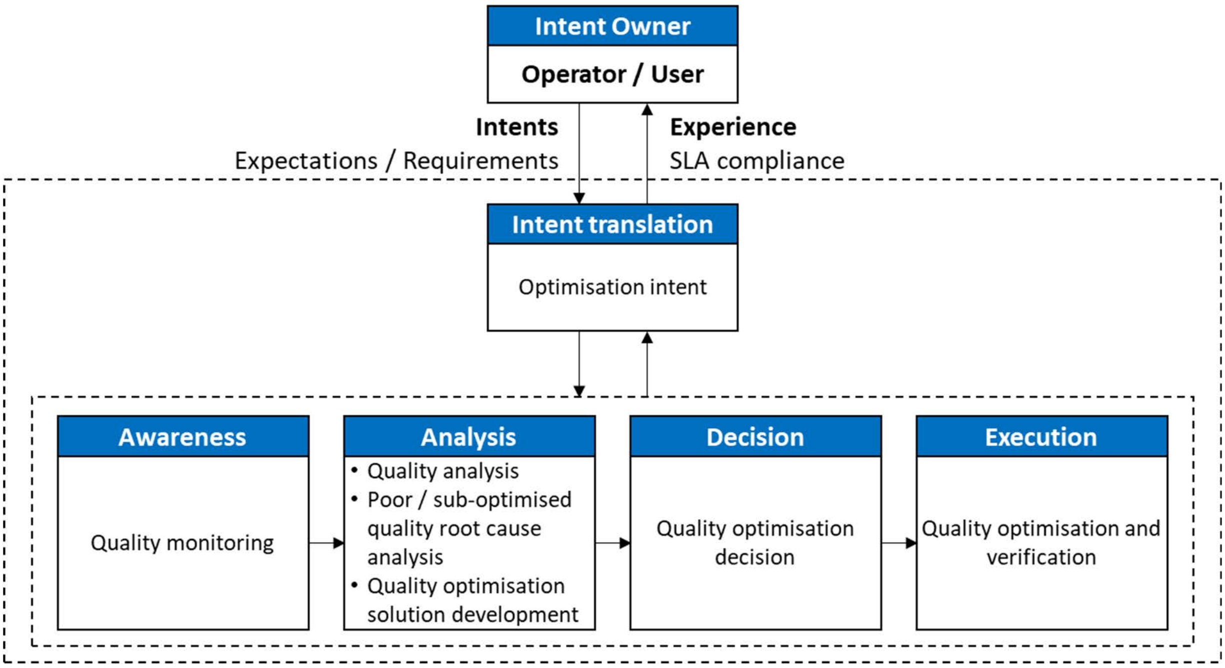

Figure 6: Optical Transport Network optimization operational sub-tasks and their mapping to the general tasks in the Autonomous Network general workflow

- **Intent translation:**
  - **Optimization intent:** Based on the network quality and service SLA objectives, determine the network and service optimization requirements.
- **Awareness:**
  - **Quality monitoring:** Monitor the network and service quality, by collecting and cleaning the related performance data from the NEs.
- **Analysis:**
  - **Quality analysis:** Periodically analyse and predict network quality problems, and service quality problems.

EXAMPLE 1: Network quality problems may be fibre attenuation or OCh bit errors.

EXAMPLE 2: Service quality problems may be increased network delay, availability deterioration, or intermittent disconnection.

  - **Poor / sub-optimized quality root cause analysis:** Analyse the network and service performance data, to perform accurate demarcation and location of the root causes of the potential quality problems.

EXAMPLE 3: Potential quality problems may be physical location of fibre deterioration, or optical power degradation.

  - **Quality optimization solution development:** Based on quality analysis and root cause demarcation and location, results to the optimization solution and confirmation of its feasibility through solution simulation.
- **Decision:**
  - **Quality optimization decision:** Review and determine the final optimization solution, based on the results of optimization solution development and simulation.
- **Execution:**
  - **Quality optimization and verification:** Execute the final optimization solution, and verify the optimization results by comparing the KPIs before and after the optimization.

7.1.4.2 Autonomous Network level classification

The Autonomous Network level (from L0 to L5) classification for the Optical Transport Network optimization is determined based on the participation of human and automation systems.

Table 5 describes the Autonomous Network levels for the seven operational sub-tasks (optimization intent, quality monitoring, quality analysis, poor / sub-optimized quality root cause analysis, quality optimization solution development, quality optimization decision, and quality optimization and verification) for the Optical Transport Network optimization.

Table 5: Autonomous Network level classification for the Optical Transport Network optimization

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Optimization intent (Intent translation)	Manually determine the network areas and services that need to be monitored.	Manually translate the network assurance requirements into specific optimization operation methods.	1. Manually input the monitoring requirements based on the pre-defined templates in the system. 2. The system automatically translates the monitoring requirements into the monitoring rule.	1. Manually configure the monitoring rules in the system. 2. The system automatically performs different network monitoring operations in different situations, based on the configured rules.	1. Manually determine the network areas and services that need to be monitored. 2. The system automatically generates the monitoring rules, and automatically applies the monitoring rules to the network.	Full-scenario and full-lifecycle automation. The system automatically performs optimization intent, quality monitoring and analysis, poor / sub-optimized quality root cause analysis, quality optimization solution development, decision, execution and verification. Support the automatic online learning and optimization for AI model iteration.
Quality monitoring (Awareness)	1. Each NE collects its performance data. 2. Manually process the collected data.	1. The system collects the NE performance data on-demand. 2. Manually use tools to analyse and process the performance data.	1. The system automatically collects quality performance data from the NEs every 15 minutes or every 24 hours. 2. Manually use tools to analyse and process the performance data.	1. The system automatically collects quality performance data from the NEs every 15 minutes or every 24 hours. 2. The system automatically analyses and processes the performance data.	1. The NEs collect performance data (including optical layer performance data) per seconds or per milliseconds. 2. The NEs perform data pre-processing, and upload the results to the system per minutes. 3. The system performs correlation analysis on the performance data collected from the NEs.	
Quality analysis (Analysis)	Manually perform network quality analysis and service impact analysis.	Manually use tools to perform network quality analysis and service impact analysis.	1. Based on fixed rules, the system analyses the historical quality performance data (EXAMPLE 1: bit error threshold), and evaluates the quality problems if any. 2. The system assists with manual service impact analysis.	1. Based on configured rules, the system analyses historical quality performance data and evaluates service and network quality problems if any. EXAMPLE 2: delay, bandwidth, and jitter. 2. The system automatically analyses the service impact and generates related early warnings.	1. The NEs automatically analyses the NE-level quality problems if any (EXAMPLE 3: poor quality of transmitted / received optical signals), and generates related early warnings. 2. The system automatically analyses network-level quality problems if any (EXAMPLE 4: optical layer quality deterioration, or service reliability risks), and generates related early warnings.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Poor / sub-optimized quality root cause analysis (Analysis)	Manually use tools to access each NE onsite, to query related information and locate the quality problems if any.	1. Manually use tools to export the current or historical alarms, performance data, and logs. 2. Manually perform correlation analysis and locate the quality problems if any.	The system provides related functions to assist with manual poor / sub-optimized quality demarcation and location. EXAMPLE 5: showing the alarms and logs associated with the service path graphically.	Based on the pre-configured rules (including alarm correlation rules and dynamic threshold rules), the system automatically locates the quality problems (EXAMPLE 6: fibre deterioration), and assist with manual confirmation on the poor / sub-optimized quality demarcation and location.	Both the NEs and the management and control system perform accurate poor / sub-optimized quality demarcation and location, based on the high-precision performance data collected in seconds or milliseconds. EXAMPLE 7: the exact physical location that causes optical-layer deterioration, poor service quality or intermittent service interruption.	
Quality optimization solution development (Analysis)	Manually develop the quality optimization solution.	Manually use tools to develop the quality optimization solution.	The system provides optimization suggestions based on the manual poor-quality demarcation and location. EXAMPLE 8: software parameter modification and route adjustment.	The system automatically provides possible causes of poor-quality problems, and provides suggestions to assist with manual optimization solution development.	The system automatically develops quality optimization solutions. EXAMPLE 9: route adjustment and optical-layer performance optimization.	
Quality optimization decision (Decision)	Manually determine the quality optimization solution.	Manually use tools to determine the quality optimization solution.	Manually evaluate the quality optimization solution, based on the optimization suggestions output by the system.	The system automatically provides possible causes of poor-quality problems, and provides suggestions to assist with manual determination of the quality optimization solution.	The system automatically evaluates and determines the quality optimization solution.	
Quality optimization and verification (Execution)	1. Manually perform the quality optimization. 2. Manually verify the optimization results.	1. Manually use tools to perform the quality optimization. 2. Manually use tools to verify the optimization results.	1. Manually trigger the system to automatically execute the quality optimization solution. 2. Manually trigger the system to verify the optimization results.	1. Manually trigger the system to automatically execute the quality optimization solution. 2. The system automatically verifies the optimization results.	1. The system automatically triggers the execution of the quality optimization solution. EXAMPLE 10: route optimization and optical-layer performance optimization. 2. The system automatically verifies the optimization results.	

7.2 Autonomous Network level classification for Access and Residential Networks

7.2.1 Planning and deployment

7.2.1.1 Operational sub-tasks

The planning and deployment operation workflow of the Access and Residential Network is divided into six operational sub-tasks:

- Network requirement prediction
- Resource determination and analysis
- Network planning solution development
- Network planning decision
- Deployment configuration
- On-site acceptance

NOTE 1: The planning and deployment operation workflow focuses on the planning and deployment of operators' PON Access Network elements.

These six operational sub-tasks are mapped to the five different general tasks (intent translation, awareness, analysis, decision and execution) in the Autonomous Network general workflow, as shown in Figure 7.

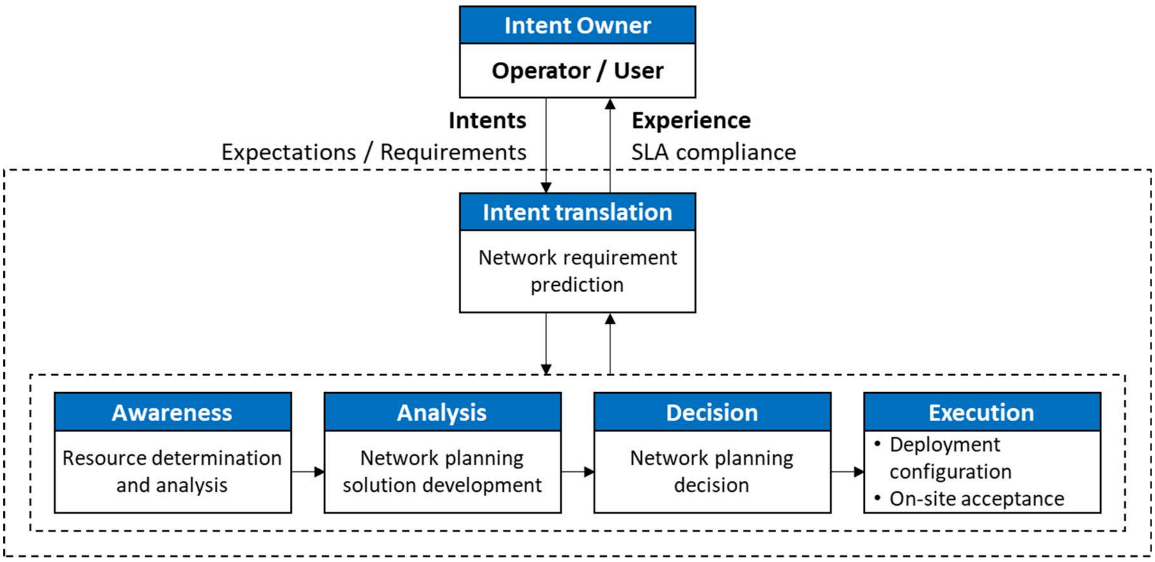

Figure 7: Access and Residential Network planning and deployment operational sub-tasks and their mapping to the general tasks in the Autonomous Network general workflow

NOTE 2: The users in the Access Network are the residential broadband users.

- **Intent translation:**
  - **Network requirement prediction:** Output the network planning requirements\ to the network operator or to the system, based on multiple input factors such as users' service requirements, network operator's service development objectives and network deployment plans.

EXAMPLE 1: Network planning requirements may be network coverage and capacity requirements, or resiliency, to name a few.

- **Awareness:**
  - **Resource determination and analysis:** Collect the current network resource information, and generate statistics and perform analysis on resource usage.
- **Analysis:**
  - **Network planning solution development:** Based on the network planning requirements and the determination and analysis of the current network resource, output the overall network planning result to the network planner (as document) or to the system (in a machine-readable format), and provide the detailed network planning, including the networking, Optical Line Terminal (OLT) board type selection, fibre connection, and parameter configuration.
- **Decision:**
  - **Network planning decision:** Based on the outcome of the network planning and the simulation results, evaluate whether the network planning requirements are satisfied.
- **Execution:**
  - **Deployment configuration:** Complete on-site hardware and software installation deployment of the operator's Access Network, based on the network planning and simulation results, to ensure that all the Access NEs in PON are correctly operating and managed. Complete the initial configuration on the Access Network.

EXAMPLE 2: The initial configuration of Access Network may be, logical fibre connection configuration, optical performance commissioning and service configuration.

  - **On-site acceptance:** Test and accept the operator's deployed Access Network, including service connectivity and quality test.

EXAMPLE 3: Testing and acceptance of the operator's deployed Access Network use metering and flow detection.

7.2.1.2 Autonomous Network level classification

The Autonomous Network level (from L0 to L5) classification for the Access and Residential Network planning and development is determined based on the participation of human and automation systems.

Table 6 describes the Autonomous Network levels for the six operational sub-tasks (network requirement prediction, resource determination and analysis, network planning solution development, network planning decision, deployment configuration, and on-site acceptance) for the Access and Residential Network planning and development.

Table 6: Autonomous Network level classification for the Access and Residential Network planning and development

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Network requirement prediction (Intent translation)	Manually analyse and determine the network requirements	1. Manually use auxiliary tools to collect the current status information of the PON resource. 2. Manually analyse and determine the network requirements.	1. The system automatically collects the PON resource information. 2. Manually analyse the network resource usage, and predict the users' service requirements.	1. The system automatically collects and analyses the PON resource usage (including the NEs, ports, traffics, and numbers of registered users and online users), and performs preliminary resource analysis.	The system uses AI models to analyse and predict the network requirements (EXAMPLE 1: predicting the user number increase, bandwidth upgrade, and service level improvement), based on the service changes (EXAMPLE 2: bandwidth, latency, and service preference).	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
				2. Manually predict the network requirements based on the resource analysis by the system. EXAMPLE 3: network capacity expansion requirements.		
Resource determination and analysis (Awareness)	Manually determine the resource allocation and analysis of the resource usage.	1. Manually use auxiliary tools to obtain the physical active resource information. 2. Manually determine the resource allocation and analysis of the resource usage. See note.	1. The system automatically obtains the physical active resource information. 2. The system automatically generates statistics and performs analysis of the resource usage. See note.	1. The system automatically obtains the physical resource information (including both active and passive resource information). 2. The system automatically generates statistics and performs analysis on resource usage (EXAMPLE 4: slots, ports, bandwidth, optical splitter ports, and Optical Network Units (ONUs)). 3. The resource determination and analysis are based on configurable rules. EXAMPLE 5: network inventory, physical connections, service paths, and bandwidth resource.	1. Same criteria as step 1 in L3. 2. Same criteria as step 2 in L3. 3. The system identifies the resource bottleneck (based on the network requirement prediction in the previous operational sub-task). 4. The resource determination and analysis are based on rules automatically generated by the system, and are performed remotely and automatically.	Full-scenario and full-lifecycle automation. The system automatically performs the network requirement prediction, the resource determination and analysis, the network planning solution development and decision, the deployment configuration, and the on-site acceptance. Support automatic online learning and optimization for AI model iteration.
Network planning solution development (Analysis)	1. Manually analyse the network resource bottleneck. 2. Manually develop the planning solution.	1. Manually analyse the network resource bottleneck. 2. Manually develop the planning solution with templates and auxiliary tools. EXAMPLE 6: historical project case library.	1. The system assists the human to analyse the network resource bottleneck based on fixed rules. 2. The system develops the network planning solution based on the pre-configured templates.	1. The system analyses the network resource bottleneck based on rules with configurable parameters. EXAMPLE 7: configurable parameters may be port usage, optical power, and bandwidth budget. 2. The system provides a recommended high-level solution based on the analysis result.	1. The system uses the AI models to analyse resource bottlenecks. EXAMPLE 8: resource usage trend prediction. 2. Same criteria as step 2 in L3.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Network planning decision (Decision)	Manually make decisions based on expert experience.	Same criteria as L0.	1. Manually adjust the network planning solution developed by the system. 2. Manually make decisions based on expert experience.	1. Based on the configurable templates, the system automatically generates the detail network planning solutions. EXAMPLE 9: OLT physical and logical resource design, security design, and reliability design. 2. Same criteria as step 2 in L2.	1. The system uses the AI models to automatically generate the detail network planning solutions, based on the networking requirements. EXAMPLE 10: user scale, packages, and convergence ratio. 2. The system automatically determines the optimal network planning solution from the alternative solutions.	
Deployment configuration (Execution)	Manual integrated configuration on the Access NEs in PON.	Manual integrated configuration on the Access NEs in PON, using auxiliary tools.	1. Based on fixed templates, the system automatically configures part of the Access NEs in PON in some limited scenarios. EXAMPLE 11: NE management configuration and software deployment configuration. 2. Remaining configurations are completed manually.	Based on configurable templates and the integrated network planning solution, the system automatically controls the Access NEs in PON (with NE Identifier automatically configured), delivers configuration data to the NEs, detects exceptions, and completes commissioning if necessary.	1. The system uses AI models to automatically configure the Access Network, assisting with network installation and deployment. 2. The system uses AI models to automatically perform engineering commissioning and NE configuration optimization.	
On-site acceptance (Execution)	Manually perform on-site acceptance using appropriate instruments and tools.	Same criteria as L0.	1. The on-site tools automatically perform single-site acceptance. 2. The tools automatically generate NE-level acceptance reports.	1. On-site tools automatically perform site acceptance and transmit the acceptance data back to the system. EXAMPLE 12: NE configuration, software and hardware versions, NE running status, and optical path performance. 2. Based on the received site acceptance data, the system automatically performs the network-level acceptance, and generates the acceptance report.	1. The system automatically performs acceptance based on AI models (EXAMPLE 13: AI-based image recognition and coherent optical intelligent detection), with the assistance of robots. 2. The system automatically generates an acceptance report.	
NOTE: Obtaining the passive resource information is not supported at this level.						

7.2.2 Fulfilment

7.2.2.1 Operational sub-tasks

Access and Residential Network fulfilment mainly includes service provisioning, service maintenance, and customer complaint handling while the service is in operation. The objectives of Access and Residential Network fulfilment are to reduce the service provisioning time, to minimize the user complaints, and to reduce the customer complaint handling time.

The key fulfilment operation scenario is service provisioning, which includes seven operational sub-tasks:

- Service provisioning scheduling
- Resource confirmation
- Service configuration solution development
- Service configuration decision
- Network configuration
- On-site installation
- Service testing

These seven operational sub-tasks are mapped to the five different general tasks (intent translation, awareness, analysis, decision and execution) in the Autonomous Network general workflow, as shown in Figure 8.

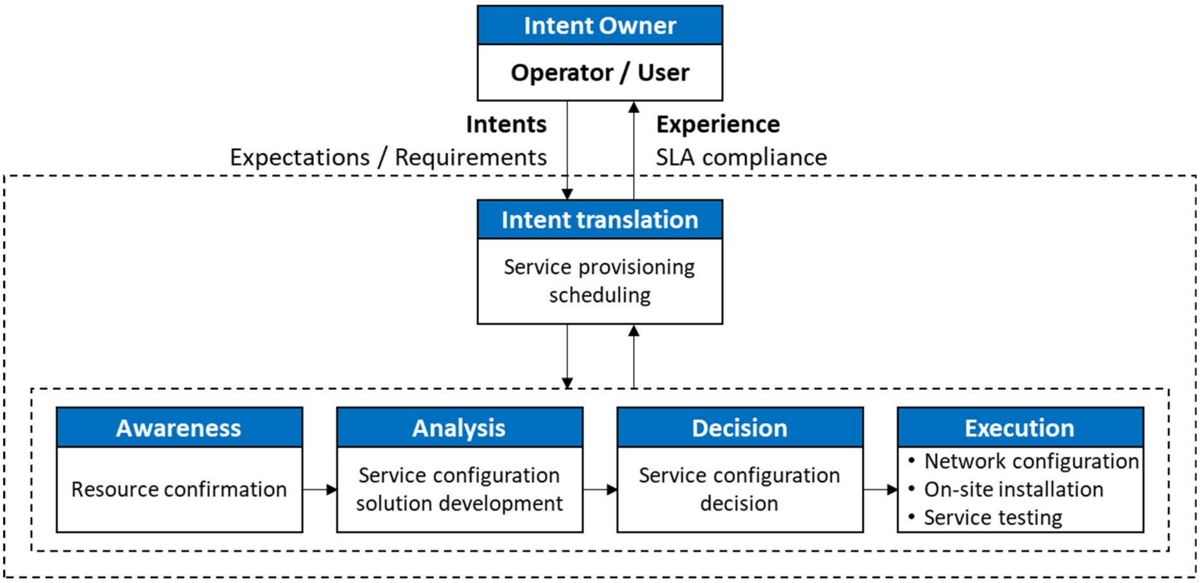

Figure 8: Access and Residential Network fulfilment operational sub-tasks and their mapping to the general tasks in the Autonomous Network general workflow

- **Intent translation:**
  - **Service provisioning scheduling:** Analyse the service provisioning requirements and translate them into network requirements, and schedule the service provisioning process based on the requirements.

EXAMPLE 1: Translated network requirements may be Access Network type, protection requirements, latency and bandwidth requirements.

- **Awareness:**
  - **Resource confirmation:** Perform network resource analysis, based on the user's service requirements and the real-time network status.

EXAMPLE 2: Resource analysis maybe, resource status, available ports, link bandwidth, resource usage, and latency.

- **Analysis:**
  - **Service configuration solution development:** Based on the resource confirmation result, develop the service provisioning solutions and emulate the services.
- **Decision:**
  - **Service configuration decision:** Determine the final service provisioning solution, ensuring that the service provisioning requirements are satisfied.
- **Execution:**
  - **Network configuration:** Based on the service configuration solution, configure the Access Network and activate the service on the network.
  - **On-site installation:** Perform the on-site installation of residential fibres and network devices, power on and activate the ONUs (including Primary Optical Network Units (P-ONUs) and Edge Optical Network Units (E-ONUs) in Fibre-To-The-Room (FTTR) scenarios), configure the internet, and perform on-site self-check on the resource usage and construction norms.
  - **Service testing:** Verify and confirm the service provisioning, check the service connectivity, and verify whether the SLAs are met.

NOTE: If there is not enough resource for the service provisioning, the planning and deployment operational tasks will be implemented to add more resource in PON. See clause 7.2.1 of the present document.

7.2.2.2 Autonomous Network level classification

The Autonomous Network level (from L0 to L5) classification for the Access and Residential Network fulfilment is determined based on the participation of human and automation systems.

Table 7 describes the Autonomous Network levels for the seven operational sub-tasks (service provisioning scheduling, resource confirmation, service configuration solution development, service configuration decision, network configuration, on-site installation, and service testing) for the Access and Residential Network fulfilment.

Table 7: Autonomous Network level classification for the Access and Residential Network fulfilment

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Service provisioning scheduling (Intent translation)	Manually schedule the service provisioning process.	Manually record the service provisioning request in a service order, and manually schedule the service provisioning process based on the service order.	1. Manually schedule the service provisioning process based on auxiliary tools with pre-configured fixed rules. 2. Manually check the validity of the service provisioning process.	1. The service provisioning process are generated based on templates. 2. The system automatically checks the validity of the service provisioning process, based on fixed rules. 3. Manually confirm the service provisioning process.	1. The system automatically translates the service intent into the service order. 2. The system automatically checks the validity of the service provisioning process, based on configurable rules. 3. Manually confirm the service provisioning process.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Resource confirmation (Awareness)	Manually confirm the resources.	Manually use the work orders to record the resources, and manually confirm the resources.	Manually use auxiliary tools to confirm the resources.	The system uses the AI image recognition methods to automatically confirm the resources, based-on configurable rules. EXAMPLE 1: network inventory, physical connections, service paths, and bandwidth resource.	The system supports automatic configuration of resource survey rules (including optical power and bandwidth budget parameters). Intelligent technologies (EXAMPLE 2: coherent optical intelligent detection technology) are used to implement automatic system survey that matches network capability rules.	Full-scenario and full-lifecycle automation. The system automatically performs the service provisioning scheduling, the resource confirmation, the service configuration solution development, the service configuration decision, the network configuration, the on-site installation, and the service testing. Support the automatic online learning and optimization for AI model iteration.
Service configuration solution development (Analysis)	Manually generate and simulate the service configuration solutions.	Same criteria as L0.	Manually trigger the system to automatically generate the service configuration solutions, only in some limited scenarios.	The system automatically generates the service configuration solutions, based on the configurable templates.	The system automatically recommends the optimal service configuration solutions based on multiple factors. EXAMPLE 3: networking solution, slicing configuration, and Wi-Fi® air interface configuration.	
Service configuration decision (Decision)	Manually make the service configuration decision.	Same criteria as L0.	Manually make the service configuration solution decisions, based on the solutions generated in the solution development sub-task.	Manually make the service configuration solution decisions based on the solutions generated by the system.	The system automatically makes the service configuration solution decisions.	
Network configuration (Execution)	Manual configuration on the Access NEs in PON.	Manual configuration on the Access NEs in PON with auxiliary tools.	The system assists with manual service configuration in some limited scenarios. EXAMPLE 4: automatic configuration based on scripts.	The system automatically configures the services on the Access Network, based on configurable templates and network configuration Application Programming Interfaces (APIs).	Same criteria as L3.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
On-site installation (Execution)	Manually perform on-site installation and maintenance.	Manually perform on-site installation and maintenance, based on auxiliary tools. EXAMPLE 5: with printed design drawings.	Manually confirm network resources (including optical path and home networking information), and configure the residential networks based on pre-set fixed rules configured in the system. EXAMPLE 6: digital TV/telephone, and home networking services.	The system automatically confirms network resources (including optical path and residential networking information), and configures the home networks based on configurable templates. EXAMPLE 7: digital TV/telephone, and home networking services.	1. The system uses AI models and/or robots to assist with the on-site installation, configuration and optimization. 2. The system automatically confirms the resource information, and verifies the on-site construction norms using AI-based image recognition methods.	
Service testing (Execution)	Manually use tools to perform service tests.	Same criteria as L0.	Manually operate the online system to test whether the SLAs are met.	Manually trigger the system to test whether the SLAs are met.	The system automatically tests whether the SLAs are met.	
NOTE: If a service fault or a service quality problem is detected during the service test, the maintenance and optimization operational tasks will be implemented. See clauses 7.2.3 and 7.2.4 of the present document.						

7.2.3 Maintenance

7.2.3.1 Operational sub-tasks

The purpose of Access and Residential Network maintenance is to reduce the fault occurrence rate and the service interruption time, reduce the manpower requirements, and therefore improve the users' service experience and reduce the operators' Operational Expenditure (OPEX).

The most important operational task for maintenance operations is to perform Access and Residential Network monitoring and troubleshooting. It includes the following eight operational sub-tasks:

- Maintenance intent
- Status collection
- Fault identification
- Potential risk identification
- Root cause analysis and location
- Fault / potential risk resolution development
- Fault / potential risk resolution decision
- Fault / potential risk handling and service verification

These eight operational sub-tasks are mapped to the five different types of general tasks (intent translation, awareness, analysis, decision and execution) in the Autonomous Network general workflow, as shown in Figure 9.

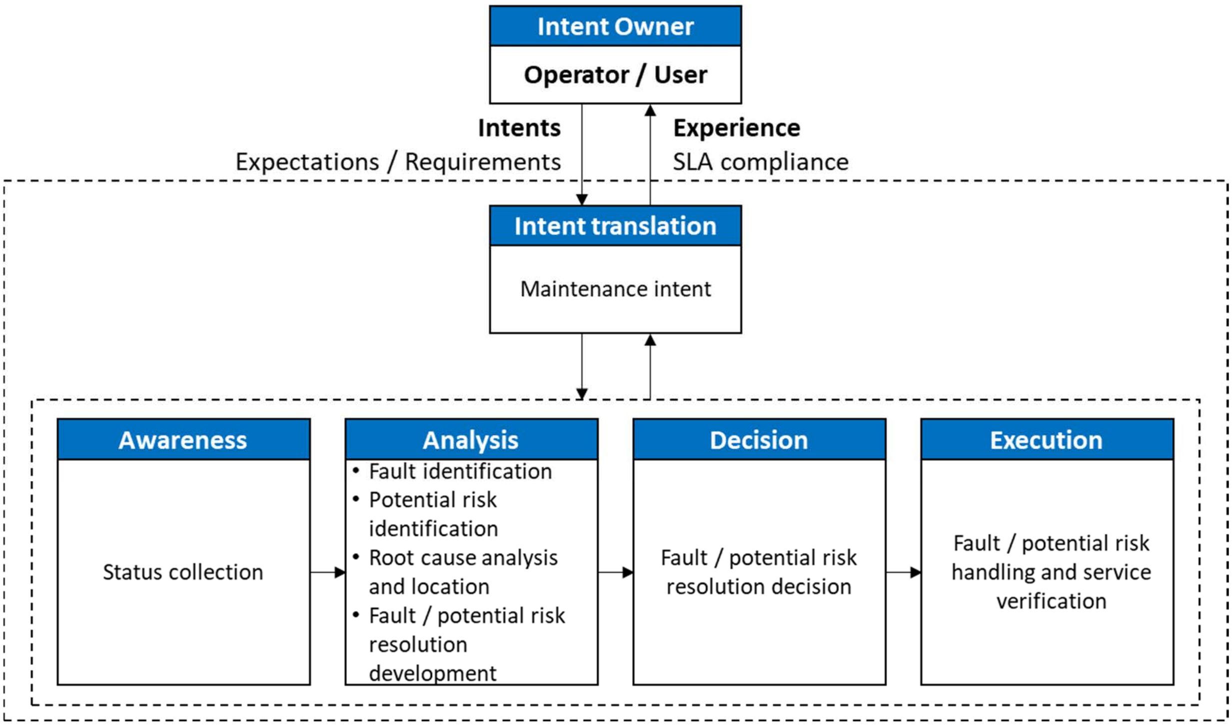

Figure 9: Access and Residential Network maintenance operational sub-tasks and their mapping to the general tasks in the Autonomous Network general workflow

- **Intent translation:**
  - **Maintenance intent:** Based on the network maintenance objectives, determine the network and service monitoring scope and monitoring requirements, such as the network reliability requirements, and the service SLA requirements.
- **Awareness:**
  - **Status collection:** Monitor and collect various status data (such as alarms and performance data) from the networks and the services, based on the monitoring requirements.
- **Analysis:**
  - **Fault identification:** Analyse and identify the network and service faults, based on the collected the network and services performance data.
  - **Potential risk identification:** Analyse and discover the potential risks in the network and potential risks to the services (prior to a real fault occurring), based on the collected performance data of the network and services.
  - **Root cause analysis and location:** Perform correlation analysis on the network based on the identified faults in any and potential identified risks. Identify the root alarms, and accurately demarcate and locate the faults.

EXAMPLE: Determine the fibre fault location, the optical power deterioration location, incorrectly configured NEs, and faulty hardware or software.

  - **Fault / potential risk resolution development:** Develop the maintenance solution based on the detected faults and potential identified risks, and the root cause.
- **Decision:**
  - **Fault / potential risk resolution decision:** Determine the network and service recovery solutions and/or potential risk elimination solutions, based on the developed maintenance solutions.

- **Execution:**
  - **Fault / potential risk handling and service verification:** Execute the solution based on the decision, and verify the execution result of the solution, including the service connectivity and SLA compliance.

7.2.3.2 Autonomous Network level classification

The Autonomous Network level (from L0 to L5) classification for the Access and Residential Network maintenance is determined based on the participation of both human and automation systems.

Table 8 describes the Autonomous Network levels for the eight operational sub-tasks (maintenance intent, status collection, fault identification, potential risk identification, root cause analysis and location, fault / potential risk resolution development, fault / potential risk resolution decision, and fault / potential risk handling and service verification) for the Access and Residential Network maintenance.

Table 8: Autonomous Network level classification for the Access and Residential Network maintenance

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Maintenance intent (Intent translation)	Manually specify the monitored area, scope and the network monitoring operations.	Manually translate the network monitoring requirements into specific network monitoring operations and fault analysis methods.	1. Manually configure the monitoring requirements on the system, based on the pre-installed monitoring templates. 2. The system automatically translates the monitoring requirements into the monitoring operation rules.	1. Manually configure the dynamic monitoring rules on the system. 2. The system automatically performs different network monitoring operations in different situations, based on the configured rules.	1. Manually specify the monitoring area and scope. 2. The system automatically translates the monitoring requirements into detailed monitoring rules, and automatically applies the rules.	Full-scenario and full-lifecycle automation. The system automatically performs maintenance intent, status collection, fault identification, potential risk identification, root cause analysis and location, fault / potential risk resolution development, resolution decision, handling and service verification. Support the automatic online learning and optimization for AI model iteration.
Status collection (Awareness)	Manually collect network status from each Access NE in PON.	Manually use tools to perform preventive maintenance inspection periodically to collect network status from each Access NE in PON.	1. The system automatically collects network status information (EXAMPLE 1: alarm data). 2. Each Access NE in PON collects performance data every 15 minutes or every 24 hours, and uploads the collected data to the management and control system.	1. The system automatically collects network status information (EXAMPLE 2: alarm data). 2. Each Access NE in PON collects performance data every 15 minutes or every 24 hours. The system supports configuring the collection rules to collect required data.	1. The system automatically collects network status information (EXAMPLE 3: alarm data). 2. Each Access NE in PON collects performance data per seconds or per milliseconds, performs data pre-processing, and uploads the processed data to the management and control system in minutes.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Fault identification (Analysis)	Manually perform fault identification, triggered by user complaints.	Manually identify the faults based on user complaints, or system alarm reports.	The system automatically collects alarm data, analyses the alarm correlation, and identifies the faults, based on pre-configured fixed rules generated from human experience. EXAMPLE 4: alarm correlation rules, and performance threshold rules.	1. The system automatically analyses the Access Network alarm correlation based on the dynamic and configurable rules. EXAMPLE 5: the correlation among the OLT/ Optical Distribution Network (ODN) /ONU equipment alarms, the Loss of Signal (LOS) / Loss of Frame (LOF) alarms and the power-off alarms, the alarm correlation between feeder fibres and distribution fibres, and the alarm correlation between boards and ports. 2. The system automatically performs root cause analysis based on the alarm correlation, to identify the faults in the Access Network.	1. The system uses AI models to automatically analyse the alarms and the root causes, and to identify the faults. 2. The system supports automatic fault identification in both the Access Network and the residential network, and identifies the priority, the impact scope, and the fault priority. EXAMPLE 6: PON device faults, PON optical path faults, ONU abnormal offline, and Wi-Fi® handover faults. 3. The system supports temporarily increasing the data collection frequency, to improve accuracy of fault identification in the case of potential risks or suspected faults.	
Potential risk identification (Analysis)	Manually perform potential risk detection, triggered by user complaints (only for those potential risks that affect users' experience. Other risks will not be identified in Level 0).	Manually identify the potential risks based on user complaints, or alarms reported by the system.	The system automatically identifies potential risks based on pre-configured fixed rules. EXAMPLE 7: a certain KPI exceeds a static threshold.	The system automatically identifies potential risks in the Access Network (EXAMPLE 8: weak optical signal in PON, or potential traffic overload on the upstream port), based on dynamic and configurable rules. These rules contain the risk identification features and profiles generated by the system.	The system uses AI models to associate multi-dimensional data, to predict and identify potential risks in the Access Network and residential network. EXAMPLE 9: potential risks may be: Equipment risks such as high temperature of the ONUs and the optical modules. Network risks such as weak Wi-Fi® coverage and Wi-Fi® interference. Software risks such as high Central Processing Unit (CPU) / memory usage caused by third-party plug-ins.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Root cause analysis and location (Analysis)	1. Manually use tools to access each Access NE in PON on site, to query related information and perform correlation analysis. 2. Manually perform fault demarcation and location.	1. Manually use tools to collect current or historical alarm information, performance data and logs. 2. Manually perform correlation analysis, fault demarcation and location.	The system provides related functions to assist with manual fault demarcation and location. EXAMPLE 10: showing the alarms and logs associated with the service path graphically.	1. The system automatically performs correlation analysis based on the pre-configured fixed rules. EXAMPLE 11: alarm correlation rules. 2. The system automatically provides possible root causes analysis remotely to assist with manual fault demarcation and location. EXAMPLE 12: remote diagnosis of PON and Wi-Fi® network faults.	1. The system supports precise demarcation and location of faults and potential risks. EXAMPLE 13: equipment hardware fault location, or fibre or wavelength interruption / deterioration location. 2. The system supports real-time diagnosis and demarcation of PON and Wi-Fi® network faults and potential risks.	
Fault / potential risk resolution development (Analysis)	Manually analyse the impact to the network and services based on the root cause, and develop the fault / potential risk resolutions.	Manually use the system to collect related information, analyse the root cause, and develop the fault / potential risk resolutions.	The system provides solution suggestions based on the fault demarcation and location.	The system provides solution suggestions for the faults or potential risks, based on the pre-configured rules.	The system automatically provides fault / potential risk resolutions, based on the accurate demarcation and location of faults or potential risks.	
Fault / potential risk resolution decision (Decision)	Manually determine the fault / potential risk resolution.	Same criteria as L0.	Manually determine the fault / potential risk resolution based on the system suggestions.	The system provides the recommended fault / potential risk resolution, assisting with manual decision-making.	The system automatically performs evaluation and determination of the fault / potential risk resolution, by using network and service simulation.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Fault / potential risk handling and service verification (Execution)	1. Manually execute the repair operation. 2. Manually verify if the affected services have been recovered from the fault / potential risk.	1. Manually use tools to execute the repair solution step by step. 2. Manually use tools to verify if the affected services have been recovered from the fault / potential risk.	1. The system automatically executes repair operation based on the pre-configured fixed rules (except for those that need to be handled on site), and the implementation effect is manually evaluated. 2. Manually trigger the system to automatically perform network and service tests for limited scenarios based on pre-set test items. EXAMPLE 14: connectivity test and network/service quality test. 3. Manually handle the exceptions detected by the system tests.	1. The system supports automatic configuration of fault handling rules, and supports pre-setting restoration paths. 2. Once a fault or potential risk is detected, the system supports automatic correction of the fault or potential risk (in both PON and Wi-Fi® networks) based on the configured rules. EXAMPLE 15: board/equipment reset and protection switch. 3. Based on the configured test items, the system automatically performs the network test to verify the services. EXAMPLE 16: connectivity test and network/service quality test.	1. The system supports remote correction of faults or potential risks based on the AI decision-making model. EXAMPLE 17: configuration error, air interface interference, and connection faults. 2. The system supports on-site fault rectification using robots. 3. The system automatically confirms the fault correction or risk elimination results, and performs service verification.	

7.2.4 Optimization

7.2.4.1 Operational sub-tasks

Network optimization mainly focuses on quality optimization. Network data are collected and analysed, to improve the resource utilization, the service quality, the energy efficiency, etc.

The optimization operation workflow for the Access and Residential Network is divided into seven operational sub-tasks:

- Optimization intent
- Quality monitoring
- Potential poor / sub-optimized quality analysis
- Root cause analysis and location
- Quality optimization solution development
- Quality optimization decision
- Quality optimization and verification

These seven operational sub-tasks are mapped to the five different types of general tasks (intent translation, awareness, analysis, decision and execution) in the Autonomous Network general workflow, as shown in Figure 10.

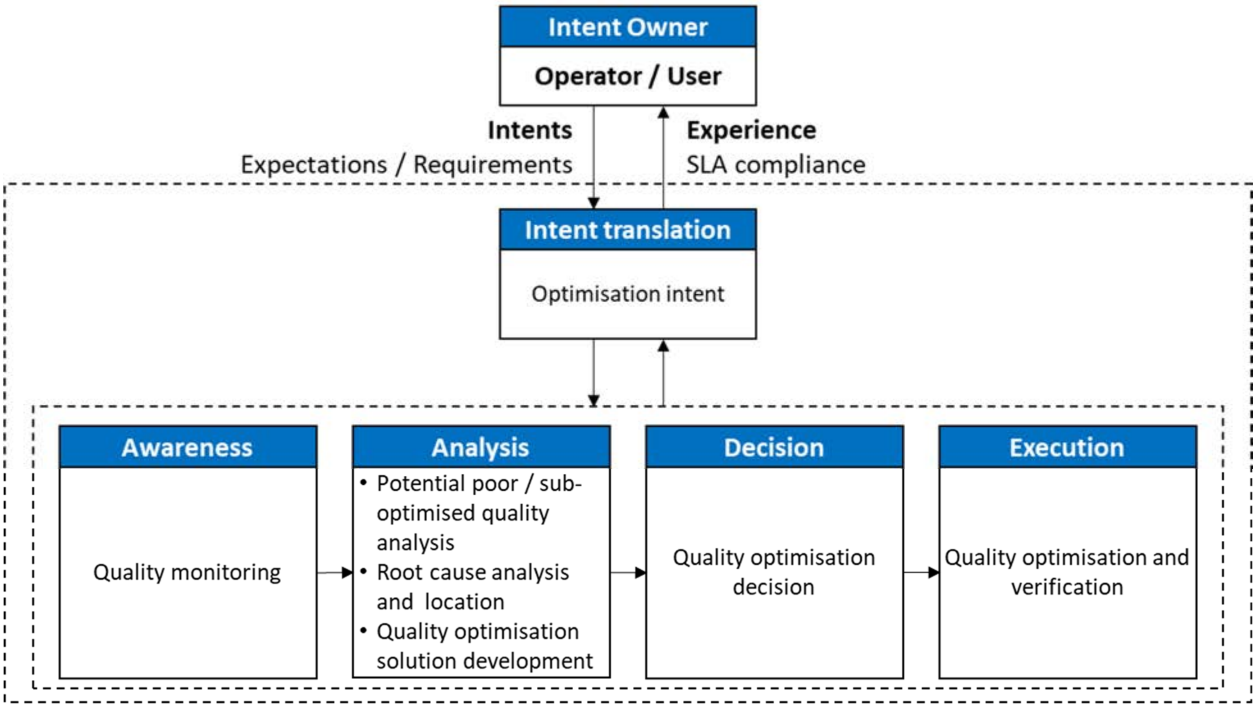

Figure 10: Access and Residential Network optimization operational sub-tasks and their mapping to the general tasks in the Autonomous Network general workflow

- **Intent translation:**
    - **Optimization intent:** Based on the network quality and service SLA objectives, determine the network and service optimization requirements.
- **Awareness:**
    - **Quality monitoring:** Monitor the network and service quality, by collecting and cleaning the related performance data from the network.
- **Analysis:**
    - **Potential poor / sub-optimized quality analysis:** Periodically analyse and predict network quality problems if any, and service quality problems if any.

EXAMPLE 1: Network quality problems may be network capacity, quality, and efficiency problems.

EXAMPLE 2: Service quality problems may be application freezing.

- **Root cause analysis and location:** Analyse the network and service performance data, to perform accurate demarcation and location of the root causes of the potential quality problems.

EXAMPLE 3: Potential quality problems include physical location of fibre deterioration or optical power deterioration, root cause identification of continuous application freezing, and bandwidth bottleneck analysis.

- **Quality optimization solution development:** Based on quality analysis and root cause demarcation and location, develops the optimization solution and confirms its feasibility through solution simulation.

- **Decision:**
    - **Quality optimization decision:** Review and determine the final optimization solution, based on the results of optimization solution development and simulation.

- **Execution:**
  - **Quality optimization and verification:** Execute the final optimization solution, and verify the optimization results by comparing the KPIs before and after the optimization.

7.2.4.2 Autonomous Network level classification

The Autonomous Network level (from L0 to L5) classification for the Access and Residential Network optimization is determined based on the participation of human and automation systems.

Table 9 describes the Autonomous Network levels for the seven operational sub-tasks (optimization intent, quality monitoring, potential poor / sub-optimized quality analysis, root cause analysis and location, quality optimization solution development, quality optimization decision, and quality optimization and verification) for the Access and Residential Network optimization.

Table 9: Autonomous Network level classification for the Access and Residential Network optimization

<table>
<tr><th>Operational sub-tasks</th><th>L0</th><th>L1</th><th>L2</th><th>L3</th><th>L4</th><th>L5</th></tr>
<tr><td>Optimization intent (Intent translation)</td><td>Manually determine the network areas and services that need to be monitored.</td><td>Manually translate the network assurance requirements into specific optimization operation methods.</td><td>1. Manually input the monitoring requirements based on the pre-defined templates in the system.
2. The system automatically translates the monitoring requirements into the monitoring rules.</td><td>1. Manually configure the monitoring rules in the system.
2. The system automatically performs different network monitoring operations in different situations, based on the configured rules.</td><td>1. Manually determine the network areas and services that need to be monitored.
2. The system automatically generates the monitoring rules, and automatically applies the monitoring rules to the network.</td><td rowspan="2">Full-scenario and full-lifecycle automation. The system automatically performs optimization intent, quality monitoring and analysis, potential poor / sub-optimized quality root cause analysis, quality optimization solution development, decision, execution and verification. Support the automatic online learning and optimization for AI model iteration.</td></tr>
<tr><td>Quality monitoring (Awareness)</td><td>1. Each Access NE in PON collects its performance data.
2. Manually process the collected data.</td><td>1. The system collects the Access NE's performance data on-demand.
2. Manually use tools to analyse and process the performance data.</td><td>1. The system automatically collects quality performance data from the Access NEs in PON every 15 minutes or every 24 hours.
2. Same criteria as step 2 in L1.</td><td>1. The system automatically collects quality performance data from the Access NEs in PON every 15 minutes or every 24 hours.
2. The system automatically analyses the performance data, based on configurable rules.
EXAMPLE 1: data sets to be collected, or dynamic threshold.</td><td>1. The Access NEs in PON collect performance data (including optical layer performance data) per seconds or per milliseconds.
2. The NEs perform data pre-processing, and upload the results to the system per minutes.
3. The system performs correlation analysis on the performance data collected from the NEs, based on AI models.</td></tr>
</table>

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Potential poor / sub-optimized quality analysis (Analysis)	Manually perform network quality analysis and service impact analysis.	Manually use tools to perform network quality analysis and service impact analysis.	1. Based on fixed rules, the system analyses the historical quality performance data (EXAMPLE 2: bit error threshold) and evaluates the quality problems if any. 2. The system assists with manual service impact analysis.	1. Based on configurable rules (EXAMPLE 3: dynamic threshold), the system automatically identifies the quality problems if any. EXAMPLE 4: link quality problems such as optical path deterioration and instability, or energy efficiency problems. 2. The system automatically analyses the impact scope. EXAMPLE 5: the services impacted by the quality problems.	1. The system automatically generates the rules based on AI models, and identifies the quality problems if any, based on the rules. EXAMPLE 6: application quality problems and bandwidth quality problems. 2. The system automatically analyses the impact scope.	
Root cause analysis and location (Analysis)	Manually use tools to access each Access NE in PON on site, to query related information and locate the quality problems if any.	1. Manually use tools to export the current or historical alarms, performance data, and logs. 2. Manually perform correlation analysis and locate the quality problems if any.	The system provides related functions to assist with manual poor / sub-optimized quality demarcation and location. EXAMPLE 7: showing the alarms and logs associated with the service path graphically.	Based on configurable rules (EXAMPLE 8: dynamic threshold rules), the system automatically locates the quality problems (EXAMPLE 9: optical path deterioration or instability problem, or poor Wi-Fi® network quality problem), and assist with manual confirmation on the poor / sub-optimized quality demarcation and location.	The system uses AI models, which replace manually configured rules, to automatically locate the quality problems based on different scenarios. EXAMPLE 10: to locate the occasional application freezing problem.	

Operational sub-tasks	L0	L1	L2	L3	L4	L5
Quality optimization solution development (Analysis)	Manually develop the quality optimization solution.	Manually use tools to develop the quality optimization solution.	Manually operate the system, to develop the quality optimization solutions based on the quality problem location result. EXAMPLE 11: software parameter modification or wireless channel adjustment.	Based on configurable rules, the system automatically develops the quality optimization solutions. EXAMPLE 12: optical layer performance optimization, Dynamic Bandwidth Assignment (DBA) / Hierarchical Quality of Service (HQoS) optimization, network-level energy efficiency configuration, and PON and Wi-Fi® poor-quality rectification suggestions.	Based on AI models, the system automatically develops quality optimization solutions. EXAMPLE 13: dynamic DBA/HQoS optimization, dynamic Wi-Fi® optimization, and specific application assurance.	
Quality optimization decision (Decision)	Manually determine the quality optimization solution.	Same criteria as L0.	Manually evaluate the quality optimization solution, based on the optimization suggestions output by the system.	The system assists with the manual evaluation of the quality optimization solution.	The system automatically evaluates and determines the quality optimization solution.	
Quality optimization and verification (Execution)	1. Manually perform the quality optimization. 2. Manually verify the optimization results.	1. Manually use tools (EXAMPLE 14: Graphical User Interface (GUI) and scripts) to perform the quality optimization. 2. Manually use tools to verify the optimization results.	1. Manually trigger the system to automatically execute the quality optimization solution. 2. Manually trigger the system to verify the optimization results.	1. Based on configurable rules, the system automatically performs the quality optimization solution, or the system automatically generates and distributes the quality optimization work orders. 2. The system automatically tests the optimization results. 3. Manually trigger the system to verify and confirm the optimization results.	1. The system automatically performs the quality optimization solution. EXAMPLE 15: dynamic DBA/HQoS optimization, dynamic Wi-Fi® optimization, and specific application assurance. Alternatively, the system automatically generates and distributes the quality optimization work orders, and robots are used to assist with the solution implementation. 2. The system automatically verifies the optimization results.	

8 Fixed network Autonomous Network level evaluation

8.1 Overview of fixed network Autonomous Network evaluation

The present document provides the general method of how to measure the fixed network Autonomous network levels, based on the Autonomous Network level classification specified in clause 7 of the present document.

The evaluation result not only provides the comprehensive score of the Autonomous Network level (L0 to L5), but also provides the individual score of each operational sub-task and scenario.

By measuring the network operation Autonomous Network level, the network operator can understand the weaknesses in intelligent network operation. This is an important input for the network operators to plan the network upgrade in order to improve the network operation intelligence.

8.2 Fixed network Autonomous Network evaluation methodology

8.2.1 Overview of evaluation steps

The Autonomous Network level evaluation includes the following five steps:

- Step 1: Determine the evaluation objects.
- Step 2: Select the evaluation scenarios.
- Step 3: Map to standard operational sub-tasks.
- Step 4: Score the evaluation object.
- Step 5: Output the evaluation conclusion.

Figure 11 below shows an example of how the Autonomous Network level of an evaluation object is evaluated. The detailed description of each evaluation step is specified in the following clauses.

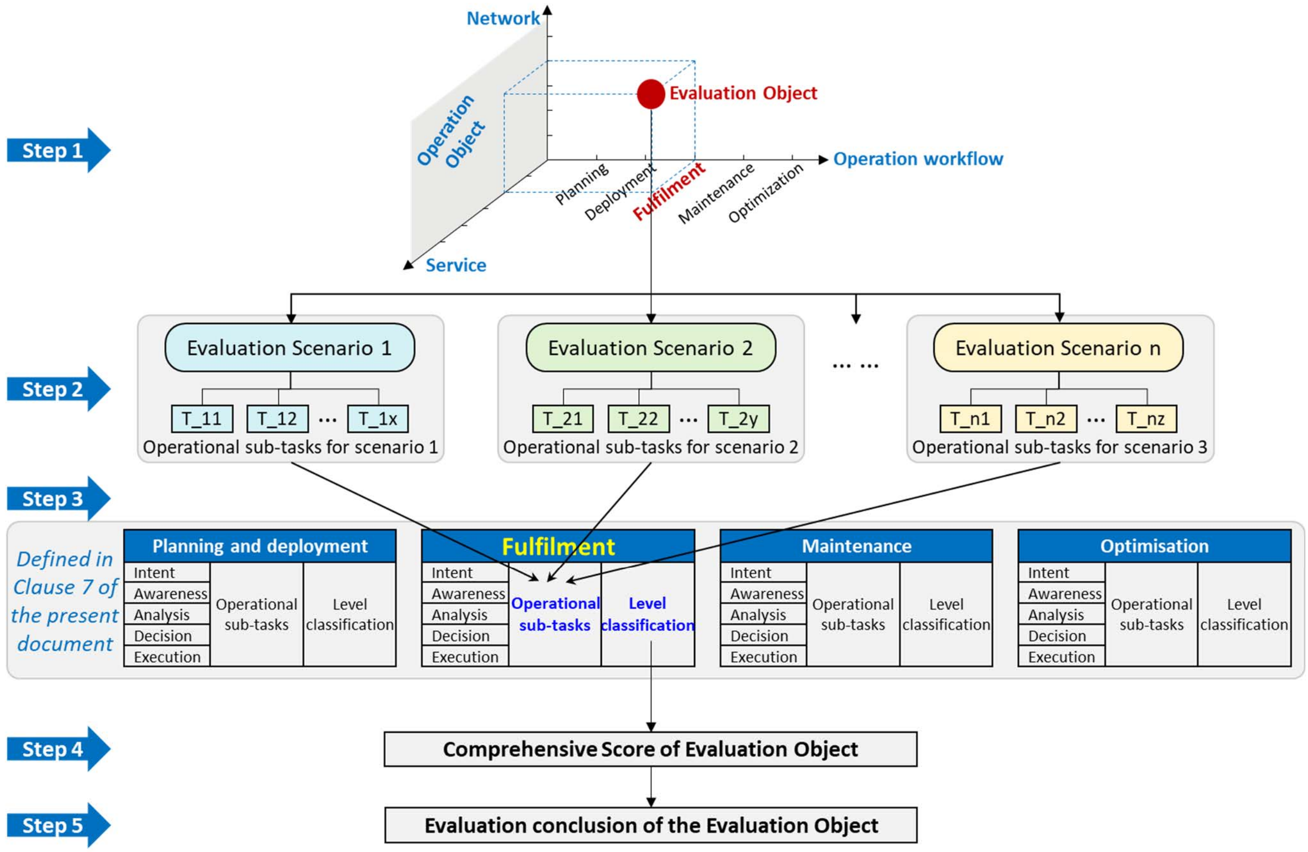

Figure 11: The five evaluation steps to measure an example evaluation object

8.2.2 Step 1: Determine the evaluation objects

An evaluation object is determined by both the operation object and the operation workflow, where the operation object includes the network type and the service type, and the operation workflow includes the planning, deployment, fulfilment, maintenance and optimization.

Figure 12 below provides an evaluation object example, in which the Autonomous Network Level of the Residential broadband service fulfilment in the PON Access Network is to be evaluated.

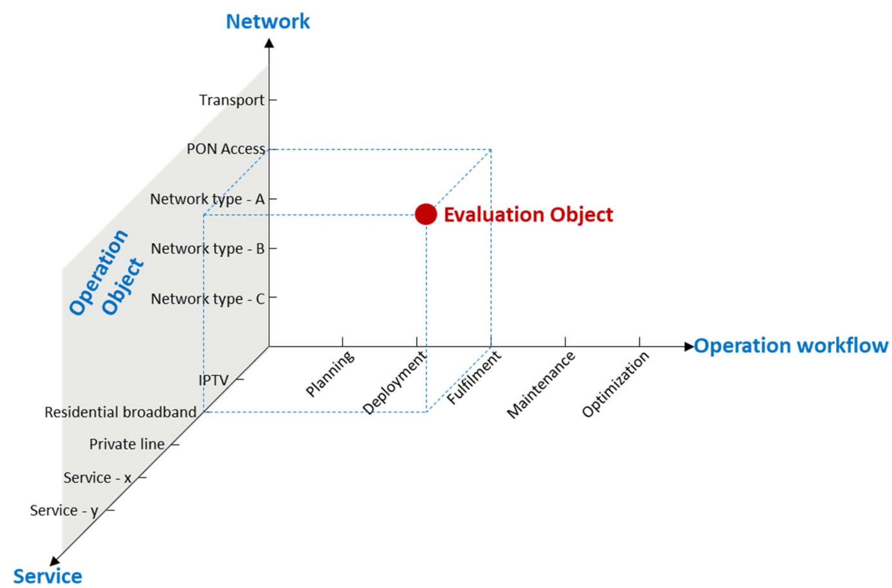

Figure 12: Example evaluation object

8.2.3 Step 2: Select the evaluation scenarios

The Autonomous Network level evaluation is scenario-based. To improve the accuracy and objectivity of the evaluation, the Network Operators may select several typical scenarios of the evaluation object for evaluation.

8.2.4 Step 3: Map to standard operational sub-tasks

Each evaluation scenario of the evaluation objects is further divided into a set of operational sub-tasks, based on the Autonomous Network general task types (i.e. intent, awareness, analysis, decision and execution).

In this way, each operational sub-task of the evaluation scenarios is mapped to one standard fixed network operational sub-task defined in clause 7 of the present document.

8.2.5 Step 4: Score the evaluation object

Based on the fixed network Autonomous Network level classification defined in clause 7 of the present document, the Autonomous Network levels of each operational sub-task are determined. Different methods may be used to evaluate the comprehensive score of the evaluation object, based on the levels of each operational sub-tasks.

The weighted average method is provided as an example in the present document.

1) Score each operational sub-task of the evaluation scenarios:

   The autonomous capability of each operational sub-task (labelled as "C_t") in each evaluation scenario is determined based on a comparison with the Autonomous Network level classification criteria (L0 to L5) described in clause 7 of the present document. Then the score of the operational sub-task (labelled as "S_t") is calculated as below:

   - If L0 <= C_t < L1, then S_t = 0
   - If L1 <= C_t < L2, then S_t = 1
   - If L2 <= C_t < L3, then S_t = 2
   - If L3 <= C_t < L4, then S_t = 3
   - If L4 <= C_t < L5, then S_t = 4
   - If C_t = L5, then S_t = 5

2) Score the evaluation scenarios of the evaluation object:

   The weight of each operational sub-task in the evaluation scenarios is set by the network operator, which may be based on different factors such as the importance or the difficulty of the tasks. The sum of all the operational sub-tasks weights in one evaluation scenario is 1.

   An evaluation scenario score is calculated using the weighted average method. Assume that there are n operational sub-tasks in an evaluation scenario, then the score of the evaluation scenario (S_sc) is:

$$S\_sc = \sum_{i=1}^{n}(S\_ti \times W\_ti)$$

Where S_ti is the score of the i^{th} operational sub-task, and W_ti is the weight of the i^{th} operational sub-task.

3) Score the evaluation object:

   Similarly, the weight of each evaluation scenario is also set by the network operator, which may be based on different factors such as the importance or the difficulty of the scenario. The sum of all the weights of the evaluation scenarios in one evaluation object is 1.

   An evaluation object score may be calculated using the weighted average method. Assume there are m evaluation scenarios in an evaluation object, then the score of the evaluation object (S_eo) is:

$$S\_eo = \sum_{j=1}^{m}(S\_scj \times W\_scj)$$

Where S_scj is the score of the j^th^ evaluation scenario, and W_scj is the weight of the j^th^ operational scenario.

Figure 13 shows an example of how the score of an evaluation object is calculated.

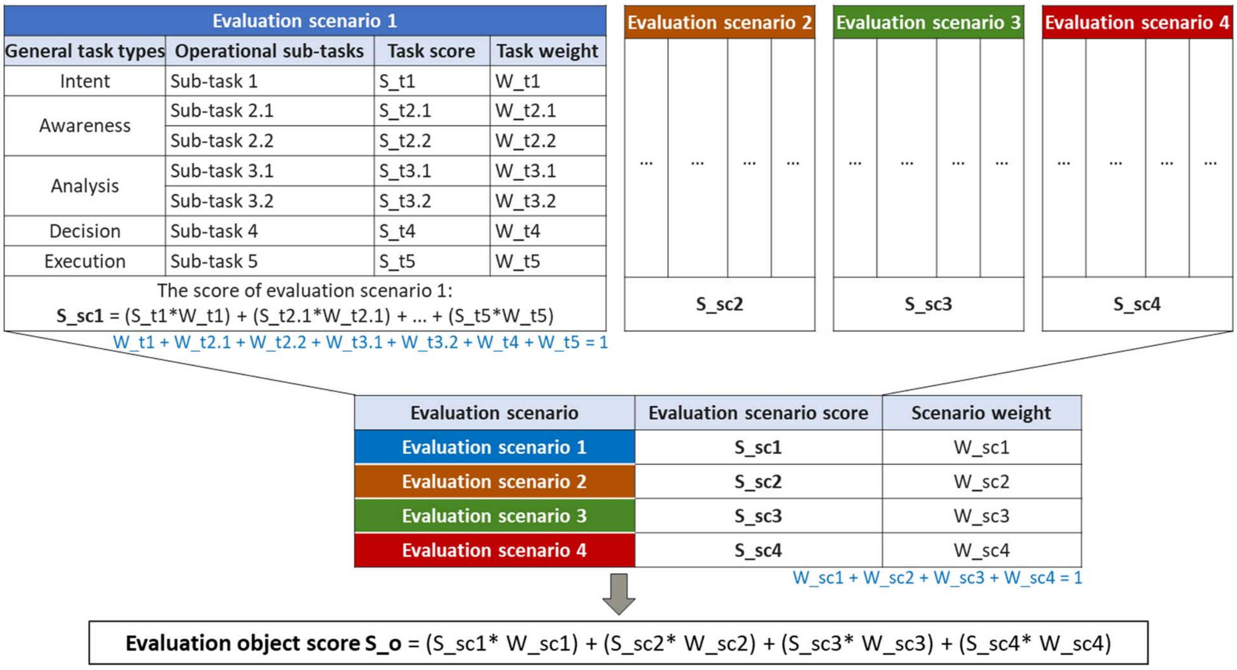

Figure 13: Example of evaluation object score calculation

8.2.6 Step 5: Output the evaluation conclusion

The evaluation conclusion includes the Autonomous Network level of the evaluation object, as well as the evaluation data generated in each evaluation step.

In the evaluation conclusion, the operational sub-tasks or evaluation scenarios with weak intelligence may be identified. Network upgrade suggestions may also be provided to guide the network operators how to improve the intelligence of their network operation.

History

Document history		
V1.1.1	April 2025	Publication