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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Future networks

Framework for evaluating intelligence levels of future networks including IMT-2020

Recommendation ITU-T Y.3173

ITU-T

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Recommendation ITU-T Y.3173

Framework for evaluating intelligence levels of future networks including IMT-2020

Summary

Recommendation ITU-T Y.3173 specifies a framework for evaluating the intelligence of future networks including IMT-2020 and a method for evaluating the intelligence levels of future networks including IMT-2020 is introduced. An architectural view for evaluating network intelligence levels is also described according to the architectural framework specified in Recommendation ITU-T Y.3172.

In addition, the relationship between the framework described in this Recommendation and corresponding work in other standards or industry bodies, as well as the application of the method for evaluating network intelligence levels on several representative use cases are also provided.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.3173	2020-02-06	13	11.1002/1000/14133

Keywords

Architecture, evaluation, IMT-2020 networks, intelligence level, network intelligence.

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Framework for evaluating intelligence levels of future networks including IMT-2020

1 Scope

This Recommendation describes a framework for evaluating the intelligence levels of future networks including IMT-2020. This includes:

– Development trend of network intelligence;

– Methods for evaluating network intelligence levels;

– Architectural view for evaluating network intelligence levels.

The appendices describe the relationship between the framework described in this Recommendation and corresponding work in other standards or industry bodies, as well as the application of the method for evaluating network intelligence levels on representative use cases.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.3172] Recommendation ITU-T Y.3172 (2019), *Architectural framework for machine learning in future networks including IMT-2020*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 machine learning pipeline [ITU-T Y.3172]: A set of logical nodes, each with specific functionalities, that can be combined to form a machine learning application in a telecommunication network.

NOTE – The nodes of a machine learning pipeline are entities that are managed in a standard manner and can be hosted in a variety of network functions [b-ITU-T Y.3100].

3.1.2 machine learning function orchestrator (MLFO) [ITU-T Y.3172]: A logical node with functionalities that manage and orchestrate the nodes in a machine learning pipeline.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 network intelligence level: Level of application of automation capabilities including those enabled by the integration of artificial intelligence techniques in the network.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI	Artificial Intelligence
API	Application Programming Interface
CM	Configuration Management
E2E	End to End
eMBB	Enhanced Mobile Broadband
ENI	Experiential Networked Intelligence
ETSI	European Telecommunications Standards Institute
GSM	Global System for Mobile Communications
GSMA	GSM Association
IoT	Internet of Things
INR	Interference and Noise
ISG	Industry Specification Group
KPI	Key Performance Indicator
MDT	Minimization of Drive Tests
MIMO	Multiple Input Multiple Output
ML	Machine Learning
MLFO	Machine Learning Function Orchestrator
mMTC	Massive Machine Type Communications
NF	Network Function
NHTSA	National Highway Traffic Safety Administration
OAM	Operation Administration and Maintenance
PM	Performance Management
RCA	Root Cause Analysis
RSRP	Reference Signal Received Power
SAE	Society of Automotive Engineers
SRC	Source
TMF	TM Forum
UE	User Equipment
URLLC	Ultra-Reliable and Low Latency Communications

5 Conventions

In this Recommendation:

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option, and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with this Recommendation.

6 Introduction

6.1 Challenges in operation, administration and maintenance of IMT-2020 networks

Along with the network evolution to IMT-2020, key performance indicators (KPIs) such as the transmission rate, transmission delay and connection scale are constantly being improved. Application scenarios are becoming increasingly abundant, and the performance and flexibility of networks are being improved. In addition, more and more network functions are deployed on cloud computing platforms. This evolution enables flexible network orchestration, automated deployment, improvement of resource utilization, and provisioning of network slicing services for verticals.

However, even though IMT-2020 brings a qualitative leap in performance and flexibility, the complexity of networks is increasing significantly. This brings unprecedented challenges to the operation, administration and maintenance (OAM) of IMT-2020 networks such as:

– The network architecture is more flexible, the network deployment scenarios are diversified, and the user requirements are personalized, thus making networks more dynamic and more complex to manage.
– The introduction of diversified terminals, such as in Internet of things (IoT), has led to growth in the number of user equipment (UE) by orders of magnitude, thus the cost of network management tends to increase.
– The use of manual decision-making mechanisms makes it difficult to quickly understand any change in network conditions and to quickly adapt the network to such changes.
– Mechanisms for utilizing and analysing the large amount of network data generated daily need to be deployed and operated in the networks, in order to produce value.
– The extensive use of network connectivity among UEs and things leads to high requirements in terms of security and the protection of data being exchanged through networks.
– The decoupling of software from the hardware in networks requires efficient management solutions to realize high-frequency updates of software being used in these networks.
– Insufficient openness of network capabilities limits the efficient utilization of network resources and the enhancement of user value.
– Given that service-based architecture is a key enabler for IMT-2020 networks, the evolution of traditional network management towards a service-based intelligent network management approach needs to be addressed.

To address the above-mentioned challenges, the introduction of automation mechanisms relying on artificial intelligence (AI) including machine learning (ML) techniques is a key aspect to be considered in network management systems. In order to solve the current efficiency and capability problems of networks, introducing network intelligence is seen as a promising approach, in particular:

– To achieve network self-maintenance, automatic optimization, intelligent operation and high-efficiency OAM, AI including ML and other technologies for automation are introduced.
– To derive value from mining of massive network data and to address security assurance issues, AI (including ML) assisted data collection and analysis can further enhance the big

data analysis capability, enable timely identification of security risks, and strengthen security measures.

– To address the problem of insufficient network openness, combining AI (including ML) techniques and virtualization technologies can improve the management capabilities and efficient use of network resources, shorten the implementation cycle of new technology applications, and accelerate its iteration.
– To help in the evolution towards intelligent network management, an approach to enable the use of AI including ML in networks is needed. [ITU-T Y.3172] describes an architectural framework that supports such approach, including for intelligent network management.
– Network intelligence levels may be used for specifying liability aspects in contractual agreements (e.g., between network operators and network equipment suppliers). For example, costs for network support contracts or insurance costs for network equipment may be determined based on network intelligence levels.

6.2 Significance of evaluating network intelligence levels

As explained in clause 6.1, AI (including ML) is considered to be a promising technology to cope with the increasing complexity and to improve the performance of future networks including IMT-2020. As networks become more and more intelligent, it is important to adopt a standard method for evaluating network intelligence levels.

A standard method for evaluating network intelligence levels has the following implications:

– It provides an evaluation basis for measuring the intelligence levels of a network and of its components.
– It helps the industry to reach a consensual and unified understanding of network intelligence concepts.
– It provides a reference for industry supervisors to formulate relevant strategies and development planning of future networks including IMT-2020 in various countries.
– It provides a decision mechanism to operators, equipment vendors and other network industry participants for planning of network technology features and products' roadmaps.

7 Methods for evaluating network intelligence levels

7.1 Dimensions for evaluating network intelligence levels

In order to evaluate network intelligence levels, this Recommendation makes use of the following five widely applicable dimensions:

a) **Demand mapping**: This dimension corresponds to the process of converting configuration or the adjustment of requirements from operation and maintenance teams into specific instructions that network components can understand and execute.

NOTE – Examples of network component are network elements and network functions. Network components are typically used in network subsystems.

b) **Data collection**: This dimension relates to the process of collecting network data required by the various analysis processes.

c) **Analysis**: This dimension refers to the process of performing an analysis (including data pre-processing) of collected networked data:

   – to obtain context information of the network (perception analysis), e.g., current operating environment, services, users and other information,

– to further predict based on historical data, the future trends in the change of the network context information and make inference for decision (prediction analysis).

d) **Decision**: This dimension corresponds to the process that takes decisions about network and/or service configuration based on the results of the analysis process.

e) **Action implementation**: This dimension is related to the process of executing corresponding configuration triggered by the decision process.

Two main areas used for evaluating network intelligence levels are workflows (related to the whole lifecycle of networks) and network subsystems (different classes of network components), since these are mainly involved in the operation and deployment of networks.

NOTE 1 – The method used by the Society of Automotive Engineers (SAE) for describing automatic driving levels provides a good reference for elaborating a method for evaluating network intelligence levels. However, as described in Appendix I, the evaluation method for network intelligence levels is much more complicated compared to the one used for automatic driving levels.

The overall network intelligence level of a whole network is a comprehensive reflection of intelligence levels of the individual workflows and subsystems.

As shown in Figure 7-1, the five dimensions identified in clause 7.1 are applicable for evaluating the network intelligence levels from both the workflow and subsystem perspectives. Figure 7-1 illustrates examples of possible workflows and subsystems to be considered for evaluating network intelligence levels.

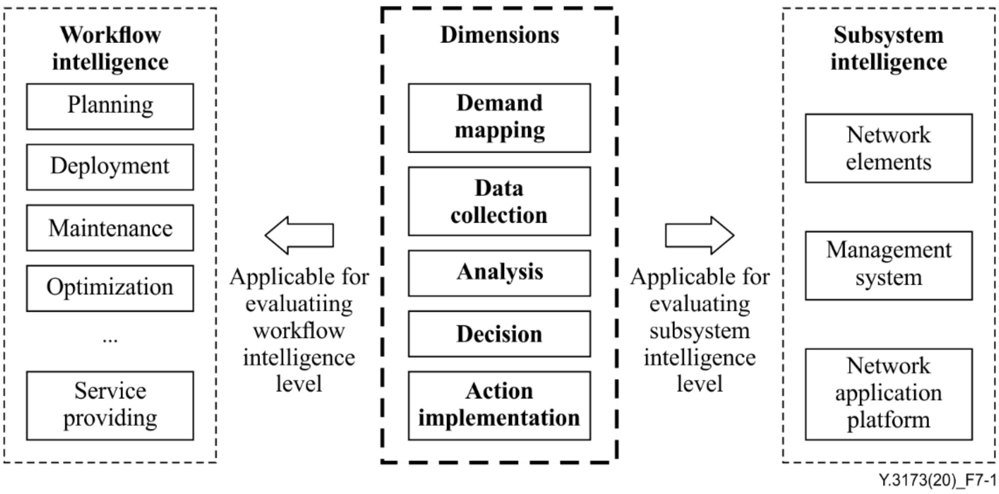

Figure 7-1 – Dimensions for evaluating network intelligence levels

The intelligence levels of individual workflows and subsystems can be determined based on the above dimensions. Only when the intelligence levels of each subsystem and workflow reach or exceed a certain level, then the intelligence level of the whole network can be regarded as reaching the corresponding level.

The workflows and the subsystems may vary from use case to use case. Hence, network intelligence capability levels when measured along a dimension may differ for each use case. Correspondingly, the intelligence levels of the network can vary depending on the use cases being considered for evaluation.

NOTE 2 – Appendix II describes various example use cases and their corresponding evaluation of network intelligence levels.

7.2 Basic method for evaluating network intelligence levels

Based on the dimensions for the evaluation of network intelligence levels described in clause 7.1, the basic method for network intelligence evaluation is described in two steps using Tables 7-1 and 7-2.

- **Step 1: Evaluating the network intelligence capability level of each dimension**

Network intelligence capability levels are identified by the following increasing order of intelligence:

a) Human;

b) Human and System;

c) System.

Table 7-1 gives the conditions under which each dimension can be classified into a given network intelligence capability level. In a use case scenario, this table can be used to determine the network intelligence capability level for each of the five dimensions, the resulting determination being provided as an input to Step 2.

Table 7-1 – Conditions for classifying dimensions into network intelligence capability levels

Dimensions	Network intelligence capability level		
	Human	**Human and System**	**System**
Action implementation	Action implementation process is performed fully by a human being.	Action implementation process is performed automatically by the system in at least one use case scenario for the given use case.	Action implementation process is performed automatically by the system in all the use case scenarios for the given use case.
Data collection	Data collection process is performed fully by a human being.	Data collection process is performed automatically by the system according to data collecting rules defined by a human being.	Data collection process is performed automatically by the system according to system defined data collecting rules.
Analysis	Analysis process is performed fully by a human being.	Analysis process is performed automatically by the system according to rules defined by a human being.	Analysis process is performed automatically by the system according to system defined/learned rules.
Decision	Decision process is performed fully by a human being.	Decision process is performed automatically by the system according to rules defined by a human being.	Decision process is performed automatically by the system according to system defined/learned rules.
Demand mapping	Demand mapping process is performed fully by a human being.	Demand mapping process is performed automatically by the system according to a template defined by a human being.	Demand mapping process is performed automatically by the system according to the intention of the use case.

- **Step 2: Determining the overall network intelligence level**

Table 7-2 provides a description of the network intelligence levels (L0 to L5).

Table 7-2 – Network intelligence levels

Network intelligence level		Dimensions				
		Action implementation	**Data collection**	**Analysis**	**Decision**	**Demand mapping**
L0	Manual network operation	Human	Human	Human	Human	Human
L1	Assisted network operation	Human and System	Human and System	Human	Human	Human
L2	Preliminary intelligence	System	Human and System	Human and System	Human	Human
L3	Intermediate intelligence	System	System	Human and System	Human and System	Human
L4	Advanced intelligence	System	System	System	System	Human and System
L5	Full intelligence	System	System	System	System	System
NOTE 1 – For each network intelligence level, the decision process has to support intervention by human being, i.e., decisions and execution instructions provided by a human being have the highest authority. NOTE 2 – It is to be noted that this table may be used to only determine the network intelligence level for each dimension (and not the overall network intelligence level).						

For each dimension, each level (L0-L5) is characterized by a required network capability level (e.g., for the L3 level, the analysis dimension should be at the human and system network capability level).

The per-dimension network intelligence capability levels obtained from Table 7-1 are used to determine the overall network intelligence level for a given use case.

The overall network intelligence level is obtained as follows:

- Determining the per-dimension network intelligence level
  - For a given dimension, the network intelligence level is determined by selecting the highest network intelligence level among the multiple network intelligence levels (L0 to L5) identified in Table 7-2 that match the network intelligence capability level evaluated for that dimension according to Step 1.
- Determining the overall network intelligence level
  - The overall network intelligence level is then determined by selecting the minimum per-dimension network intelligence level across all dimensions.

7.3 Requirements for evaluating network intelligence levels

ML-Int-level-001: The evaluation of network intelligence levels is required to be performed on the following dimensions, as specified in clause 7.1: Action implementation, data collection, analysis, decision and demand mapping.

ML-Int-level-002: For a given dimension, the evaluation of the corresponding network intelligence level is required to result in one of the following network intelligence capability levels, as specified in Table 7-1:

- Human;

- Human and System;
- System.

ML-Int-level-003: The network intelligence level evaluated for a given use case is required to correspond to one of the following levels, as specified in Table 7-2:

- L0: Manual network operation;
- L1: Assisted network operation;
- L2: Preliminary intelligence;
- L3: Intermediate intelligence;
- L4: Advanced intelligence;
- L5: Full intelligence.

ML-Int-level-004: For a given dimension, the per-dimension network intelligence level is required to be determined by selecting the highest network intelligence level among the multiple network intelligence levels (L0 to L5) that match the network intelligence capability level evaluated for that dimension as per **ML-Int-level-002.ML-Int-level-005**: For a given use case, the overall network intelligence level is required to be determined by selecting the minimum level across all per-dimension network intelligence levels determined as per **ML-Int-level-004**.

8 Architectural view on network intelligence level evaluation

This clause provides an architectural view for evaluating network intelligence levels. This includes:

– The mapping between the architectural requirements defined in [ITU-T Y.3172] and the evaluation method described in clause 7;

– An architectural framework for network intelligence level evaluation;

– A key architectural scenario for evaluating network intelligence levels.

8.1 Mapping of architectural requirements

The following requirements from [ITU-T Y.3172] already identify a need to monitor and evaluate network intelligence levels along with the functionalities provided by the network:

– REQ-ML-MNG-004 provides requirements for the management of all the ML functionalities in the network.

– REQ-ML-DEP-004 provides requirements for dynamic plug-in of new sub-systems and workflows (as source and sink).

NOTE – Appendix II.3 describes the application of the method for evaluating network intelligence level on an alarm root cause analysis (RCA) and fault recovery. The upgrade of an existing RCA implementation may include better intelligence functions and hence may increase the intelligence level of that workflow after the upgrade (e.g., data collection for RCA may now be fully automated in the upgraded implementation). This is an example of a potential change in the network which may necessitate monitoring corresponding changes in the network intelligence capability levels and evaluate the network intelligence level accordingly.

8.2 Architectural framework for network intelligence level evaluation

In this clause, an architectural framework for evaluating the network intelligence levels of components and workflows in a network is described taking into account the high-level architectural framework for machine learning in future networks including IMT-2020 [ITU-T Y.3172].

Figure 8-1 highlights the introduction of monitoring and evaluation of network intelligence levels in the architectural framework provided by [ITU-T Y.3172].

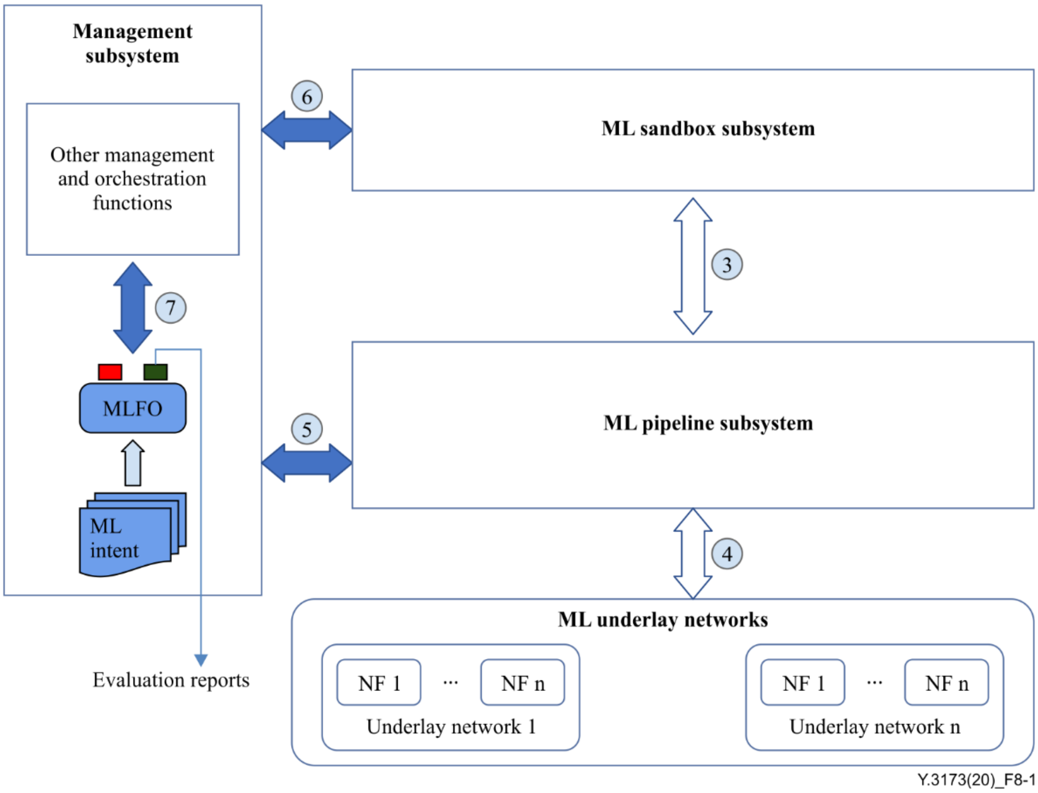

Figure 8-1 – Architectural framework for evaluating intelligence levels in the network

Although not shown in Figure 8-1, ML pipeline nodes in the ML pipeline subsystem [ITU-T Y.3172] provide support for evaluating network intelligence levels according to the dimensions described in clause 7.1. The data collection process is done by source (SRC) nodes, the analysis and decision processes are performed by ML models and policy nodes, and the action implementation process is supported by SINK nodes. In addition, the demand mapping process is done using the ML intent provided as input to the MLFO.

The reference points in Figure 8-1 are described as follows:

3: The reference point between ML sandbox subsystem and an ML pipeline subsystem, used unmodified as defined in [ITU-T Y.3172].

4: The reference point between ML pipeline subsystem and ML underlay networks corresponds to the data handling reference point, used unmodified from [ITU-T Y.3172].

5, 6: The reference points between the management subsystem and, respectively, the ML pipeline subsystem and the ML sandbox subsystem, are used for monitoring and evaluating network intelligence levels in the ML pipeline subsystem and the ML sandbox subsystem.

7: The reference point between machine learning function orchestrator (MLFO) and other management and orchestration functions of the management subsystem, defined in [ITU-T Y.3172], allows the MLFO to monitor the capabilities of ML underlay networks with respect to network intelligence.

8.3 Key architecture scenario for network intelligence level evaluation

This clause aims to describe the way the architecture framework portrayed in clause 8.2 can be used. In doing so, the following key architecture scenario, as shown in Figure 8-2, is considered, including the introduction of a ML-enabled network service in the network and query of network intelligence levels.

The major steps in the sequence diagram are listed below:

- Pre-requisite: the management subsystem instantiates the network service.
- Declarative specification of the ML underlay is made in ML intent as defined in [ITU-T Y.3172]. This is provided as an input to the MLFO.
- The MLFO parses the ML intent and instantiates the ML pipeline nodes (as defined in [ITU-T Y.3172]). In addition, it parses the monitoring and network intelligence level portion of the ML intent, and accordingly configures the monitoring reports in the ML pipeline nodes.
- The ML pipeline nodes may send periodic or asynchronous reports to the MLFO on the network intelligence levels and performance.
- Based on the reports provided by the ML pipeline nodes, the MLFO will respond to any query from the operator about the network intelligence levels.

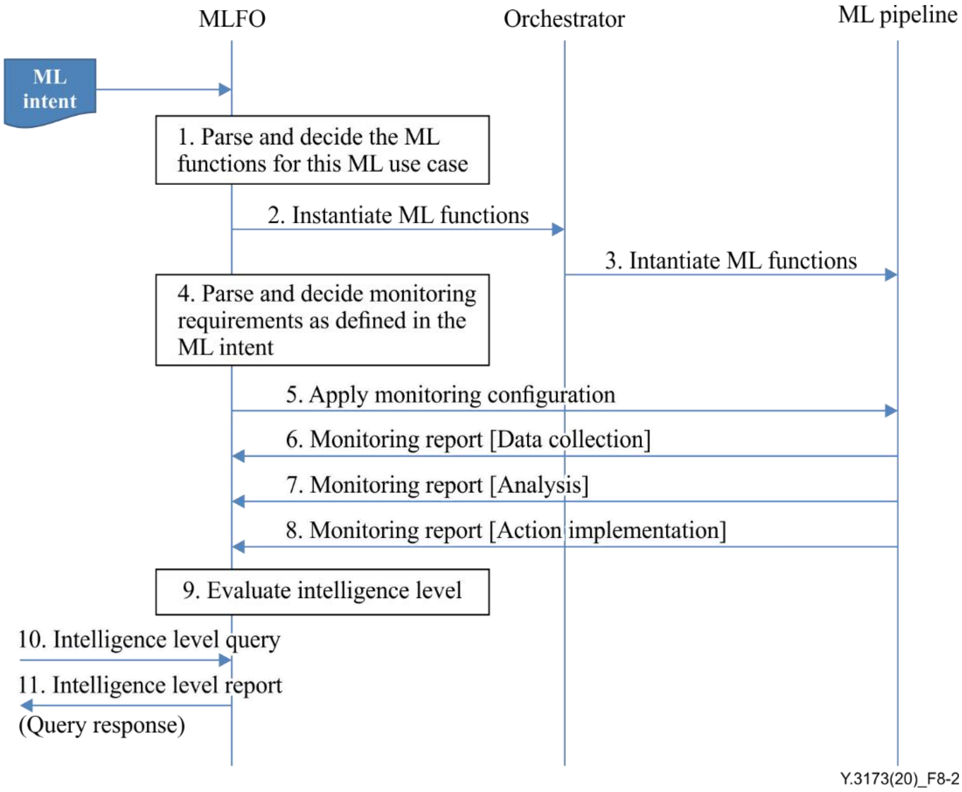

Figure 8-2 – Key architecture scenario for network intelligence level evaluation

The steps in the sequence diagram are as follows:

1: The MLFO parses the ML intent. It decides the type and position of ML functions.

NOTE 1 – For example, based on the requirements of the ML application specified in the ML intent, the source node (SRC) may be placed in the access network.

2, 3: The MLFO uses reference point 7 to trigger the orchestrator (entity inside the "other management and orchestration functions" – see Figure 8-1) to instantiate the ML functions needed for this ML use case.

NOTE 2 – For example, data handling functions [b-ITU-T Y.3174] are instantiated along with SRC and SINK nodes.

4: The MLFO decides the evaluation method and the plugin mentioned in the ML intent. The monitoring requirements are also decided based on this ML intent.

NOTE 3 – For example, the SINK node is queried to evaluate the network intelligence capability level of the action implementation dimension supported by the ML underlay.

5: The monitoring configuration is applied to the ML pipeline.

6: Monitoring reports from SRC node (s) in the ML pipeline are sent to the MLFO regarding the data collection dimension. This may indicate specific dimensions and corresponding network intelligence capabilities.

NOTE 4 – For example, a given SRC node gets the network intelligence capability level of the data collection dimension from the network function (NF) which is associated with the SRC node. The monitoring report from the SRC provides the intelligence capability level of the data collection dimension supported by the ML underlay for this use case.

7: Monitoring reports from ML model nodes in the ML pipeline are sent to MLFO regarding the analysis dimension.

NOTE 5 – For example, a given ML model node gets the network intelligence capability level of the analysis dimension from the NF which is associated with the ML model. The monitoring report from the ML model node provides the network intelligence capability level of the analysis dimension supported by the ML underlay for this use case.

8: Monitoring reports from SINK nodes in the ML pipeline are sent regarding the action implementation dimension.

NOTE 6 – For example, a given SINK node gets the network intelligence capability level of the action implementation dimension from the NF which is associated with the SINK node. The monitoring report from the SINK node provides the network intelligence capability level of the action implementation dimension supported by the ML underlay for this use case.

9: Based on the received monitoring reports from the ML pipeline nodes, the MLFO determines the network intelligence level for the use case, using the method described in this Recommendation (see clause 7).

NOTE 7 – For example, based on the reports from the SINK nodes, the network intelligence capability level of the action implementation dimension is determined as being, e.g., Level 2.

10, 11: A report is produced, or a query response is provided.

9 Security considerations

The security considerations in [ITU-T Y.3172] are applicable to this Recommendation.

Appendix I

Relation with work done in other standards or industry bodies

(This appendix does not form an integral part of this Recommendation.)

In this appendix, the relationship between the framework for evaluating network intelligence level described in this Recommendation and the corresponding work in other standards or industry bodies is discussed.

I.1 Automatic driving levels in SAE

Similar to the intelligent OAM requirements of networks in the telecommunications industry, the automotive industry has identified clear requirements for automatic driving of motor vehicles and has already carried out related research and industrialization work. Relevant research results from the automotive industry can be used as reference for evaluating network intelligence level in future networks including IMT-2020.

In 2014, the Society of Automotive Engineers (SAE) proposed the automatic driving levels in SAE [b-SAE J3016], clarifying the 6-level automatic driving rating standard (L0～L5), which have become widely accepted and used by the automotive industry. The SAE levels described in the standard are shown in Table I.1.

Table I.1 – SAE J3016 automatic driving levels

SAE level	SAE name	SAE narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of dynamic driving task	System capability (driving modes)	NHTSA level *
Human driver monitors the driving environment							
0	No automation	The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems.	Human driver	Human driver	Human driver	n/a	0
1	Driver assistance	The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving task.	Human driver and System	Human driver	Human driver	Some driving modes	1

Table I.1 – SAE J3016 automatic driving levels

SAE level	SAE name	SAE narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of dynamic driving task	System capability (driving modes)	NHTSA level *
2	Partial automation	The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving task.	System	Human driver	Human driver	Some driving modes	2
Automated driving system("system") monitors the driving environment							
3	Conditional automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene.	System	System	Human driver	Some driving modes	3
4	High automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.	System	System	System	Some driving modes	¾
5	Full automation	The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver.	System	System	System	All driving modes	
* Note: National Highway Traffic Safety Administration (NHTSA) early rating standards, now using SAE standards							

The SAE J3016 scheme determines the automatic driving level by evaluating the participation degree of the driver and the automatic driving system from four evaluation dimensions: motion control (acceleration/deceleration/steering), driving environment monitoring, fallback performance of dynamic driving task, and system capability (driving modes).

The SAE J3016 standard is widely accepted by the automotive industry and applied to industry analysis, product planning and publicity, guiding the automotive industry to carry out five stages of work to achieving self-driving goals, and helping to form a unified understanding on concepts of automatic driving, unpiloted driving, intelligent driving, etc.

As in the automotive industry, the intelligence level evaluation of telecommunication networks involves multi-faceted aspects such as use cases, network domains, workflows and services.
Note that even though the automotive industry is a good example of intelligence grading, there are some fundamental differences between the automotive industry and telecommunication industry, including the following ones:

– Telecommunication service providers offer a broad range of services, each with varying quality of service requirements, whereas the automotive industry provides a similar product to a limited number of consumer segments.
– The end-user for the evaluation of intelligence level in the automotive industry is the consumer and hence it is important to keep intelligence levels simple and easily understandable and comparable. In the telecommunication industry, the situation is more complex given that end-users for the evaluation of intelligence levels are not only traditional consumers (end-users) of telecommunication services but typically include network operators themselves, network equipment providers, supervisors (e.g., national authorities), etc., who have different skills, expertise and experience. Such evaluation in the telecommunication industry needs to consider different technical domains and underlying service requirements.

I.2 AI and automation in GSMA

This clause describes the relation of the framework for evaluating intelligence level in future networks including IMT-2020, described in this Recommendation, with a related GSM Association (GSMA) specification [b-GSMA–AI].

The key points in [b-GSMA–AI] which are relevant to the framework described in this Recommendation are:

• Ability to deploy new applications and services using open application programming interfaces (API), transferrable analytics solutions, need for operation agility and efficiency, the requirement for intelligent networks built upon AI (including ML) technologies.

  NOTE 1 – The framework for evaluating intelligence level in future networks including IMT-2020, described in this Recommendation, is built on the architectural framework for machine learning in future networks including IMT-2020 described in [ITU-T Y.3172]. The evaluation of intelligence in combination with the architectural framework [ITU-T Y.3172] helps to satisfy the requirement for intelligent networks built upon AI (including ML) technologies.

• Network automation and intelligence, which is introduced as the fourth dimension of IMT-2020 in addition to the other three fundamental dimensions (enhanced mobile broadband (eMBB), ultra-Reliable and low latency communications (URLLC), massive machine type communications (mMTC), will significantly improve operators' management efficiency.

  NOTE 2 – The framework for evaluating intelligence level in future networks including IMT-2020, described in this Recommendation, includes evaluation of automation along with AI (including ML) in various ML use cases. Thus, it enables measurement, evaluation and comparison of the networks with respect to the fourth dimension.

• Automatic closed-loop under the operator provided intent or policy is introduced as the cornerstone of network automation. This closed-loop must be cross-domain and per-domain to address the challenges in managing future networks.

  NOTE 3 – ML pipeline along with MLFO and ML sandbox [ITU-T Y.3172] allows an efficient management of multi-level ML mechanism in operator's network. ML intent provides the ability to provide operator's input and policy. In this Recommendation, it is further extended with the method for evaluation of network intelligence level and corresponding architectural views.

A harmonized classification system and supporting definitions regarding intelligent network are called for in [b-GSMA–AI]. This includes definition of intelligent network, identification of levels of intelligent network, definitions and levels on functional aspects and a step-wise progression through the levels.

This Recommendation attempts to specify these definitions and levels and describes the framework to evaluate and progress the intelligence level of networks.

I.3 Autonomous networks in TM Forum

This clause describes the relation of the framework for evaluating network intelligence level in future networks including IMT-2020, described in this Recommendation, with a related TM Forum (TMF) [b-TMF-AUTO].

The key points in [b-TMF-AUTO] which are relevant to the framework described in this Recommendation are:

- Framework for autonomous networks: this includes autonomous domains for network transformation, network automation for operations transformation and business automation for operations transformation. Operations automation with knowledge as a service is identified as the core of production efficiency and business agility.
- The following characteristics of autonomous networks are described in [b-TMF-AUTO]:

  Execution, awareness, analysis, decision, intent/experience, applicability.
- The following levels of autonomous networks are described in [b-TMF-AUTO]:

  L0: manual operation and maintenance, L1: assisted operation and maintenance, L2: partial autonomous network, L3: conditional autonomous network, L4: high autonomous network, L5: full autonomous network.

  NOTE – The TMF framework is compatible with the approach presented in this Recommendation where the multi-level ML pipeline and corresponding architecture is used as a basis to enable closed loop automation across domains and per-domain. In addition, the autonomous network levels defined in [b-TMF-AUTO] are compatible with the levels of intelligence defined in this Recommendation.

I.4 Autonomous networks in ETSI ISG ENI

This clause describes the relation of the framework for evaluating network intelligence level in future networks including IMT-2020, described in this Recommendation, with the European Telecommunication Standards Institute (ETSI) Industry Specification Group (ISG) Experiential Networked Intelligence (ENI) definition of categories for AI application to networks.

The following categories of AI-based network automation are defined in [b-ETSI ENI 007]:

- Category 0. Manual O&M
- Category 1. Assisted O&M
- Category 2. Partial automation
- Category 3. Conditional automation
- Category 4. High automation
- Category 5. Fully autonomic system

The factors affecting the network autonomicity level from a technical point of view are identified as man-machine interface, decision making participation, data collection and analysis, degree of intelligence and environment adaptability.

The factors affecting the network autonomicity level from a market point of view are identified as scheduling execution, perception monitoring, analysis and decision-making, customer experience and system capability. These are mapped to the categories described above based on the level of participation of human-operator.

NOTE – The framework described in this Recommendation relates to the network autonomicity level from a technical point of view as defined by [b-ETSI ENI 007], considered along with the level of participation of human being operator.

Appendix II

Application of the method for evaluating network intelligence level on representative use cases

(This appendix does not form an integral part of this Recommendation.)

This appendix describes the application of the method for evaluating network intelligence level on the following representative use cases:

- network coverage optimization,
- network cutover,
- alarm RCA and fault recovery,
- network resource maintenance and management,
- end to end (E2E) IoT service for utilities.

For each use case, the specific network intelligence capability level of each dimension is assumed, and the evaluation result of each dimension is highlighted in the use case table.

NOTE – For a given dimension, the highest network intelligence level is selected (see Table 7-2) among all the multiple network intelligence levels that match the identified network intelligence capability level. For example, for the "Action Implementation" dimension, L5 is selected even though L2, L3, L4 and L5 all match the "System" network intelligence capability level.

Based on the evaluation table given below for the use case, the overall network intelligence level for the use case is determined. Suggestions concerning possible upgrading of the network intelligence levels are also provided for each use case.

II.1 Network coverage optimization

This clause describes the application of the method for evaluating network intelligence level on network coverage optimization workflow.

Evaluation assumptions

The intelligence capabilities of each dimension of this use case are assumed to be evaluated as follows:

- Demand mapping: Human

  Rationale: Network coverage optimization demand mapping from coverage optimizing requirements to detailed work plan is manually completed by human (operator).

- Data collection: Human and System

  Rationale: Human (operator) decides which data to collect (e.g., measurement report, key performance indicators (KPI), site information), system periodically collect specified data. For some area, coverage related data is automatically collected by system according to human defined minimization of drive tests (MDT) tasks.

- Analysis: Human and System

  Rationale: Network coverage problem is automatically discovered by system according to human defined rules (e.g., using static thresholds and formulas), coverage optimization related solution can be suggested by system with the help of expert system.

- Decision: Human

  Rationale: Coverage optimization solution is reviewed and decided by human (operator). Instructions of coverage related adjustment are issued by human (operator).

- Action implementation: System

  Rationale: System automatically executes the new parameters according to instructions of coverage related adjustment.

Evaluation results

Table II.1 provides the result of the evaluation according to the above assumptions.

Table II.1 – Evaluation of network intelligence level on network coverage optimization

Level/Name vs Evaluation dimensions		Action implementation	Data collection	Analysis	Decision	Demand mapping
L0	Manual network operation	Human	Human	Human	Human	Human
L1	Assisted network operation	Human and System	Human and System	Human	Human	Human
L2	Preliminary intelligence	System	Human and System	Human and System	Human	Human
L3	Intermediate intelligence	System	System	Human and System	Human and System	Human
L4	Advanced intelligence	System	System	System	System	Human and System
L5	Full intelligence	System	System	System	System	System

Per-dimension network intelligence levels are assumed to have been evaluated as shown in Table II.1, the result of the evaluation being highlighted with orange coloured cells. ML-Int-level-004 from clause 7.3 is used to arrive at per-dimension network intelligence levels. By applying ML-Int-level-005 from clause 7.3 on Table II.1, this use case on network coverage optimization has a Level 2 (Preliminary Intelligence) overall network intelligence level.

Upgrading suggestions

To upgrade to the next network intelligence level, the data collection process would need to be completed automatically by the system according to system defined data collecting rules awhile the decision process would need to be completed automatically by the system according to human being defined rules.

For example, massive multiple input multiple output (MIMO) is a key technology in radio network to deliver higher capacity and coverage. However, there are technical roadblocks to efficiently tune massive MIMO using automatic data collection and decision. One of the challenges comes from a fast selection and optimization of the appropriate beam pattern. KPIs such as the antenna tilt, the reference signal received power (RSRP), the interference and noise (INR) can be monitored and analysed automatically to select the best beam pattern based on AI which allows a learning and iterative approach. Thus, adding capability for automatic data collection and decision would raise the network intelligence level of the use case and hence enable better network coverage.

II.2 Network cutover

This clause describes the application of the method for evaluating network intelligence level on network cutover workflow.

Evaluation assumptions

The intelligence capabilities of each dimension of this use case are assumed to be evaluated as follows:

- Demand mapping: Human

  Rationale: Manual analysis of current situations and the demand necessity are needed to convert the cutover operations into network operations.

- Data collection: Human and System

  Rationale: Cutover related data (e.g., Alarm, Configuration, Log, external) are collected by system. Humans decide which data to collect.

- Analysis: Human and System

  Rationale: Analysis for network cutover is performed with the assistance of system based on rules pre-set by humans.

- Decision: Human

  Rationale: The decision is reviewed and decided by humans.

- Action implementation: System

  Rationale: Based on the decision outcome, system automatically completes the cutover execution.

Evaluation results

Table II.2 provides the result of the evaluation according to the above assumptions.

Table II.2 – Evaluation of network intelligence level on network cutover

Level/Name vs Evaluation dimensions		Action implementation	Data collection	Analysis	Decision	Demand mapping
L0	Manual network operation	Human	Human	Human	Human	Human
L1	Assisted network operation	Human and System	Human and System	Human	Human	Human
L2	Preliminary intelligence	System	Human and System	Human and System	Human	Human
L3	Intermediate intelligence	System	System	Human and System	Human and System	Human
L4	Advanced intelligence	System	System	System	System	Human and System
L5	Full intelligence	System	System	System	System	System

Per-dimension network intelligence levels are assumed to have been evaluated as shown in Table II.2, the result of the evaluation being highlighted with orange coloured cells. ML-Int-level-

004 from clause 7.3 is used to arrive at per-dimension network intelligence level. Also, applying ML-Int-level-005 from clause 7.3 on the evaluation Table II.2, this use case on network cutover has a Level 2 (Preliminary Intelligence) overall network intelligence level.

Based on the evaluation table this use case is currently at Level 2 (Preliminary Intelligence). To reach Level 3 (Intermediate Intelligence), the system should implement automatic data collection and decision.

II.3 Alarm RCA and fault recovery

This clause describes the application of the method for evaluating network intelligence level on an alarm root cause analysis (RCA) and fault recovery.

Evaluation assumptions

The intelligence capabilities of each dimension of this use case are assumed to be evaluated as follows:

- Demand mapping: Human and System

  Rationale: For specific alarm and fault types, based on the pre-set rules, alarm and fault recovery demand mapping is completed by the system. Demand mapping about fault prediction and early warning is manually completed by a human operator.

- Data collection: System

  Rationale: The system can automatically collect the data (e.g., configuration management (CM), Alarm, performance management (PM), etc.) needed for alarm RCA according to system defined data collecting rules.

- Analysis: Human and System

  Rationale: For specific alarm and fault types, the system can summarize the generated analysis rules (e.g., data pre-processing rules, analysis of formulas and thresholds, etc.) based on experts' experience, assist manual alarm RCA, generate association rules. The above alarm RCA rules are updated manually.

- Decision: Human and System

  Rationale: For some specific alarm and fault types, based on the association rules and fault recovery proposals, the system can automatically decide the alarm root cause and fault recovery solution.

- Action implementation: System

  Rationale: Based on the decision outcome, system can automatically perform alarm filtering and root cause association and perform specific operations in the fault recovery solution.

Evaluation results

Table II.3 provides the result of the evaluation according to the above assumptions.

Table II.3 – Evaluation of network intelligence level on alarm RCA and fault recovery

Level/Name vs Evaluation dimensions		Action implementation	Data collection	Analysis	Decision	Demand mapping
L0	Manual network operation	Human	Human	Human	Human	Human
L1	Assisted network operation	Human and System	Human and System	Human	Human	Human
L2	Preliminary intelligence	System	Human and System	Human and System	Human	Human
L3	Intermediate intelligence	System	System	Human and System	Human and System	Human
L4	Advanced intelligence	System	System	System	System	Human and System
L5	Full intelligence	System	System	System	System	System

Per-dimension network intelligence levels are assumed to have been evaluated as shown in Table II.3, the result of the evaluation being highlighted with orange coloured cells. ML-Int-level-004 from clause 7.3 is used to arrive at per-dimension network intelligence level. Also, applying ML-Int-level-005 from clause 7.3 on the evaluation Table II.3, this use case on alarm root cause analysis and fault recovery has a Level 2 (Preliminary Intelligence) overall network intelligence level.

Based on the evaluation table, alarm RCA and fault recovery use case are at Level 3 (Intermediate intelligence). To upgrade to the next level, the analysis and decision processes would need to be completed automatically by the system according to system defined rules. For example, utilizing AI for correlation analysis of multi-dimensional data (e.g., alarm, performance, and network data), accurate location of alarm root cause and fault self-healing could be reached successfully.

II.4 Network resource maintenance and management

This clause describes the application of the method for evaluating network intelligence level on the network resource maintenance and management workflow.

Evaluation assumptions

The intelligence capabilities of each dimension of this use case are assumed to be evaluated as follows:

- Demand mapping: Human

  Rationale: Translation on the requirements of network resource maintenance and management (e.g., resource allocation or customization for service providing and deployment) to detailed execution plan is manually completed by human (operator).

- Data collection: Human and System

  Rationale: Resource related data (e.g., physical resource data, logical resource data) of which to be collected are decided by human (operator). In certain cases, resource related data are collected automatically by the system based on predefined rules by human.

- Analysis: Human and System

  Rationale: Query and analysis on the collected resource data are performed based on human-defined criteria with the help of expert system to generate solutions for resource maintenance and management.
- Decision: Human

  Rationale: The solution to perform resource maintenance and management (e.g., specific resource allocation for network slicing or routing adjustment) is reviewed and decided by human (operator).
- Action implementation: System

  Rationale: The system can automatically perform resource allocation or change based on the decision result.

Evaluation results

Table II.4 provides the result of the evaluation according to the above assumptions.

Table II.4 – Evaluation of network intelligence level on network resource maintenance and management

Level/Name vs Evaluation dimensions		Action implementation	Data collection	Analysis	Decision	Demand mapping
L0	Manual network operation	Human	Human	Human	Human	Human
L1	Assisted network operation	Human and System	Human and System	Human	Human	Human
L2	Preliminary intelligence	System	Human and System	Human and System	Human	Human
L3	Intermediate intelligence	System	System	Human and System	Human and System	Human
L4	Advanced intelligence	System	System	System	System	Human and System
L5	Full intelligence	System	System	System	System	System

Per-dimension network intelligence levels are assumed to have been evaluated as shown in Table II.4, the result of the evaluation being highlighted with orange coloured cells. ML-Int-level-004 from clause 7.3 is used to arrive at per-dimension network intelligence level. Also, applying ML-Int-level-005 from clause 7.3 on the evaluation Table II.4, this use case on network resource maintenance and management has a Level 2 (Preliminary Intelligence) overall network intelligence level.

To upgrade to a higher level, the capability of related dimensions would have to be improved accordingly. For example, to advance to Level 3 (Intermediate Intelligence), the data collection process would need to be completed automatically by the system with system defined rules while the decision process would need to be completed automatically by the system with human being defined rules.

II.5 E2E IoT service for utilities

This clause describes the application of the method for evaluating network intelligence level on E2E IoT service for utilities.

Evaluation assumptions

The intelligence capabilities of each dimension of this use case are assumed to be evaluated as follows:

- Demand mapping: Human

  Rationale: Service planning and deployment of IoT service is manually completed by a human operator.
- Data collection: Human and System

  Rationale: Human operator decides which data to collect for some data sources (e.g., PM, CM, alarm, probe, external), system periodically reports back the specified data. Some data sources (e.g., event traces) are initiated by human operator which may be for a limited time or a region.
- Analysis: Human and System

  Rationale: Service assurance evaluations (such as anomaly detection, trend analysis, coverage gap, utilization) are performed by the system based on pre-set rules by human operator.
- Decision: Human and System

  Rationale: Human operator defines policies to specify required action based on analysis results. E.g., a human-defined rule to delay data transmission to off-peak hours is triggered by the system when network utilization exceeds a threshold.
- Action implementation: System

  Rationale: Based on the decision outcome, system automatically modifies required device parameters over the air interface.

Evaluation results

Table II.5 provides the result of the evaluation according to the above assumptions.

Table II.5 – Evaluation of network intelligence level on E2E IoT service for utilities

Level/Name vs Evaluation dimensions		Action implementation	Data collection	Analysis	Decision	Demand mapping
L0	Manual network operation	Human	Human	Human	Human	Human
L1	Assisted network operation	Human and System	Human and System	Human	Human	Human
L2	Preliminary intelligence	System	Human and System	Human and System	Human	Human
L3	Intermediate intelligence	System	System	Human and System	Human and System	Human

Table II.5 – Evaluation of network intelligence level on E2E IoT service for utilities

Level/Name vs Evaluation dimensions		Action implementation	Data collection	Analysis	Decision	Demand mapping
L4	Advanced intelligence	System	System	System	System	Human & System
L5	Full intelligence	System	System	System	System	System

Per-dimension network intelligence levels are assumed to have been evaluated as shown in Table II.5, the result of the evaluation being highlighted with orange coloured cells. ML-Int-level-004 from clause 7.3 is used to arrive at per-dimension network intelligence level. Also, applying ML-Int-level-005 from clause 7.3 on the evaluation Table II-1, this use case on E2E IoT service for utilities has a Level 2 (Preliminary Intelligence) overall network intelligence level.

The system needs to decide which data source would have to be activated for analysis to advance to Level 3 (Intermediate Intelligence). To further advance to Level 4 (Advanced Intelligence), the analysis and decision processes would need to be automatically done by the system and service planning and the deployment workflow would need to be automated using pre-specified templates. To reach Level 5 (Full Intelligence), intent-based service planning and deployment would need to be implemented.

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