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Keywords: architecture, evaluation, IMT-2020 networks, intelligence; level; network intelligence level

Abstract: This is the output draft of Recommendation ITU-T Y.ML-IMT2020-Intelligence-level developed at the Q20/13 Geneva meeting, October 2019.

This is the output draft of Recommendation ITU-T Y.ML-IMT2020-Intelligence-level developed at the October 2019 Q20/13 Geneva meeting. It is put forward for consent.

Draft new Recommendation ITU-T Y.3173 (formerly Y. ML-IMT2020-Intelligence-level)

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

Summary

The objective of this Recommendation is to specify a framework for evaluating intelligence of future networks including IMT-2020. A method for evaluating intelligence level of future networks including IMT-2020 is introduced. An architecture view for evaluating network intelligence level is also described according to the architectural framework specified in [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 level on several representative use cases are also provided.

Keywords

architecture, evaluation, IMT-2020 networks, intelligence; level; network intelligence level

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

1. Scope

This Recommendation describes a framework for evaluating intelligence level in future networks including IMT-2020. This includes:

- Development trend of network intelligence;
- Method for evaluating network intelligence level;
- Architecture view for evaluating network intelligence level.

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 level 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] ITU T Recommendation 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 terms:

3.2.1 Network intelligence level: in the context of this Recommendation, the 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
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
NHTSA	National Highway Traffic Safety Administration
NOP	Network Operator
OAM	Operation Administration and Maintenance
PM	Performance Management
RCA	Root Cause Analysis
SAE	Society of Automotive Engineers
SRC	Source
TMF	TM Forum
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, the key performance indicators such as the transmission rate, transmission delay and connection scale are constantly being improved, the application scenarios are becoming more and more abundant, and the performance and flexibility have fundamentally been improved. 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, though IMT-2020 brings a qualitative leap in performance and flexibility, the complexity of the network is increasing significantly. This brings unprecedented challenges to the operation, administration and maintenance (OAM) of IMT-2020 networks:

- The network architecture is more flexible, the network deployment scenarios are diversified, and the user requirements are personalized, thus making the network 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 UEs by orders of magnitude, thus the cost of network management increases.
- Manual decision making mechanism makes it difficult to quickly understand and adapt the network.
- The huge amount of new data generated every day from the network needs to be analyzed and utilized, so as to produce value.
- Convenient and extensive network connection digitizes and interconnects the behaviour of the people and things. There is a requirement of data security protection in such an interconnected network.
- Traditional network software and hardware are tightly coupled, and the frequency of update of the solution implementation is too low.
- Insufficient openness of network capabilities limits the efficient utilization of network resources and the enhancement of user value.
- Service based architecture is a key enabler for IMT-2020 networks. Evolution of traditional network management to service-based intelligent network management approach is needed.

To solve the above mentioned issues in the management of networks, automation mechanisms including based on artificial intelligence (AI) including machine learning (ML) techniques are key. The industry hopes to solve the current efficiency and capability problems of the networks with the help of introducing network intelligence. 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) technology and virtualization technology can improve the management capability and efficiency 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.
- To provide considerations while arriving at some contractual terms between parties. For example, insurance or support terms may be arrived at based on the evaluation of network intelligence level.

6.2 Significance of evaluating network intelligence level

As explained in clause 6.1 above, AI (including ML) is considered to be a promising technology to cope with the increasing complexity and improve the performance of future networks including IMT-2020. At present, the focus of standardization organizations or industry bodies is mainly on the applications of AI (including ML) in the network. As networks become more and more intelligent, it is important to adopt a standard method for evaluating network intelligence level.

An industry-approved method for evaluating network intelligence level has the following significances:

- It provides evaluation basis for measuring the intelligence level of a network and its components.
- It helps the industry to reach a consensus and unified understanding of the concepts of intelligent network.
- 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 decision support to operators, equipment vendors and other network industry participants for technology and planning for products roadmaps.

7. Methods for evaluating network intelligence level

7.1 Dimensions for evaluating network intelligence level

In order to evaluate network intelligence level, five widely-applicable dimensions are identified.

a) **Demand Mapping**: The process of converting configuration or adjustment requirements from operation and maintenance staff into specific instructions that the network device can understand and execute.

b) **Data Collection**: The process of collecting network data required by various network functions.

c) **Analysis**: Based on the collected network data, this process performs data analysis (including data pre-processing), to obtain the context information of the network, e.g. current operating environment, services, users and other information (perception analysis), or based on the historical data to further predict the future change trend of the above content, and make inference for decision (prediction analysis).

d) **Decision:** Based on analysis results, this process takes decision about network and/or service configuration or adjustment.

e) **Action Implementation**: The process of executing corresponding configuration or adjustment triggered by the decision process.

Two main areas for evaluating network intelligence level 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- A method used by the Society of Automotive Engineers (SAE) for automatic driving level provides a good reference for method for evaluating network intelligence level. However, as described in Appendix I, the evaluation method for network intelligence level is much more complicated compared to automatic driving levels.

As shown in Figure 7-1, the five dimensions identified above are applicable for evaluating the network intelligence level from both the workflow and subsystem perspectives.

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

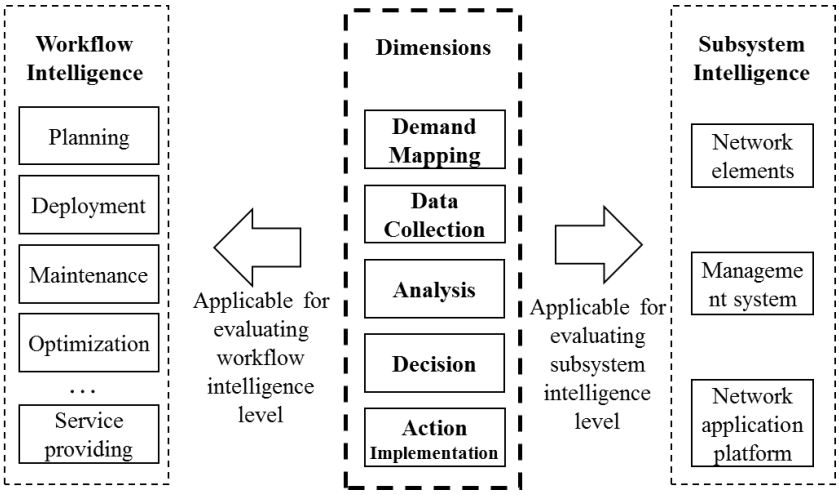

Figure 7-1 Dimensions for evaluating network intelligence level

The intelligence level of individual workflows and subsystems can be determined based on the above dimensions. Only when the intelligence level of each subsystem and workflow reaches or exceeds a certain level, 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, the network intelligence capability level when measured along a dimension may differ for each use case. Correspondingly, the intelligence level 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 level

Based on the dimensions for evaluation of network intelligence level as 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

The following network intelligence capability levels are identified, in the increasing order of intelligence:

a) Human

b) Human & System

c) System

Table 7-1 gives the conditions under which each dimension can be classified into each network intelligence capability level. Given a use case, this table can be used to determine the network intelligence capability level of each dimension, which is input to Step 2.

Table 7-1 Conditions for network intelligence capability level evaluation on per-dimension basis

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

■ Step 2: Evaluating the overall network intelligence level

Table 7-2 shows the network intelligence level evaluation. The per-dimension network intelligence capability levels obtained from Table 7-1 are used to evaluate the overall network intelligence level for a given use case.

The overall network intelligence level is obtained as follows:

- Evaluating the per-dimension network intelligence level
  - For a given dimension, the highest network intelligence level is selected among the multiple network intelligence levels in Table 7-2 which match the network intelligence capability level identified in Step 1.
- Evaluating the overall network intelligence level
  - The overall network intelligence level is finally determined by using the minimum intelligence level across all dimensions.

Table 7-2 Network intelligence level evaluation

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 & System	Human & System	Human	Human	Human
L2	**Preliminary intelligence**	System	Human & System	Human & System	Human	Human
L3	**Intermediate intelligence**	System	System	Human & System	Human & System	Human
L4	**Advanced intelligence**	System	System	System	System	Human & System
L5	**Full intelligence**	System	System	System	System	System

NOTE 1- The decision process in each level has to support human intervention, i.e. human reviewed decision and execution instructions have the highest authority.

NOTE 2- In certain implementations of the evaluation of network intelligence levels, the dimensions may be independently evaluated.

7.3 Requirements for the architecture framework for evaluating network intelligence level

ML-Int-level-001: The following dimensions are required to be used evaluating the intelligence level of networks: Action Implementation, Data Collection, Analysis, Decision and Demand Mapping.

ML-Int-level-002: For each dimension used for evaluating the intelligence level of networks the following network intelligence capability levels are required to be used, as specified in Table 7-1:

- Human
- Human & System
- System

ML-Int-level-003: The evaluation of network intelligence level for a given use case is required to indicate one of the following levels as a result, 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 evaluated as the highest network intelligence level among the multiple network intelligence levels specified in Table 7-2 which match the network intelligence capability level identified in **ML-Int-level-002.**

ML-Int-level-005: For a given use case, the overall network intelligence level is required to be evaluated as the minimum level across all per-dimension network intelligence levels as identified in **ML-Int-level-004**.

8. Architecture view on network intelligence level evaluation

In this clause, the relation between the dimensions mentioned in clause 7.1 and the ML pipeline nodes in [ITU T Y.3172] is used to provide an architecture view for evaluating network intelligence level, including the mapping between architecture requirements defined in [ITU T Y.3172] and the evaluation method defined in clause 7.

NOTE- The relation between the dimensions mentioned in clause 7.1 and the ML pipeline nodes in [ITU T Y.3172] is as follows: data collection is done by SRC node, analysis and decision is done by ML models and Policy nodes, action implementation is done by SINK node and demand mapping is done using the ML Intent.

8.1 Architecture framework for network intelligence level evaluation

In this clause, an architecture framework for evaluating network intelligence level of the components and workflows in the network is specified.

[ITU T Y.3172] defines the high-level architecture framework for Machine Learning in future networks including IMT-2020. REQ-ML-MNG-004 [ITU T Y.3172] specifies the management of all the ML functionalities in the network. Dynamic plug-in of new sub-systems and workflows (as source and sink) is specified in REQ-ML-DEP-004. These two requirements identify a need to monitor and evaluate the network intelligence level along with the functionalities provided by the network.

NOTE- As an example, a third party software provider to the network operator (NOP) may update the root cause analysis (RCA) implementation. The new version of the RCA function may include better intelligence functions and hence may increase the intelligence level of that workflow (e.g. data collection for RCA may now be fully automated by the vendor implementation). A standard mechanism is needed to monitor such changes in the network intelligence capability levels and evaluate the network intelligence level accordingly.

The following figure highlights the introduction of monitoring and evaluation of network intelligence level in the architecture framework provided by [ITU-T Y.3172].

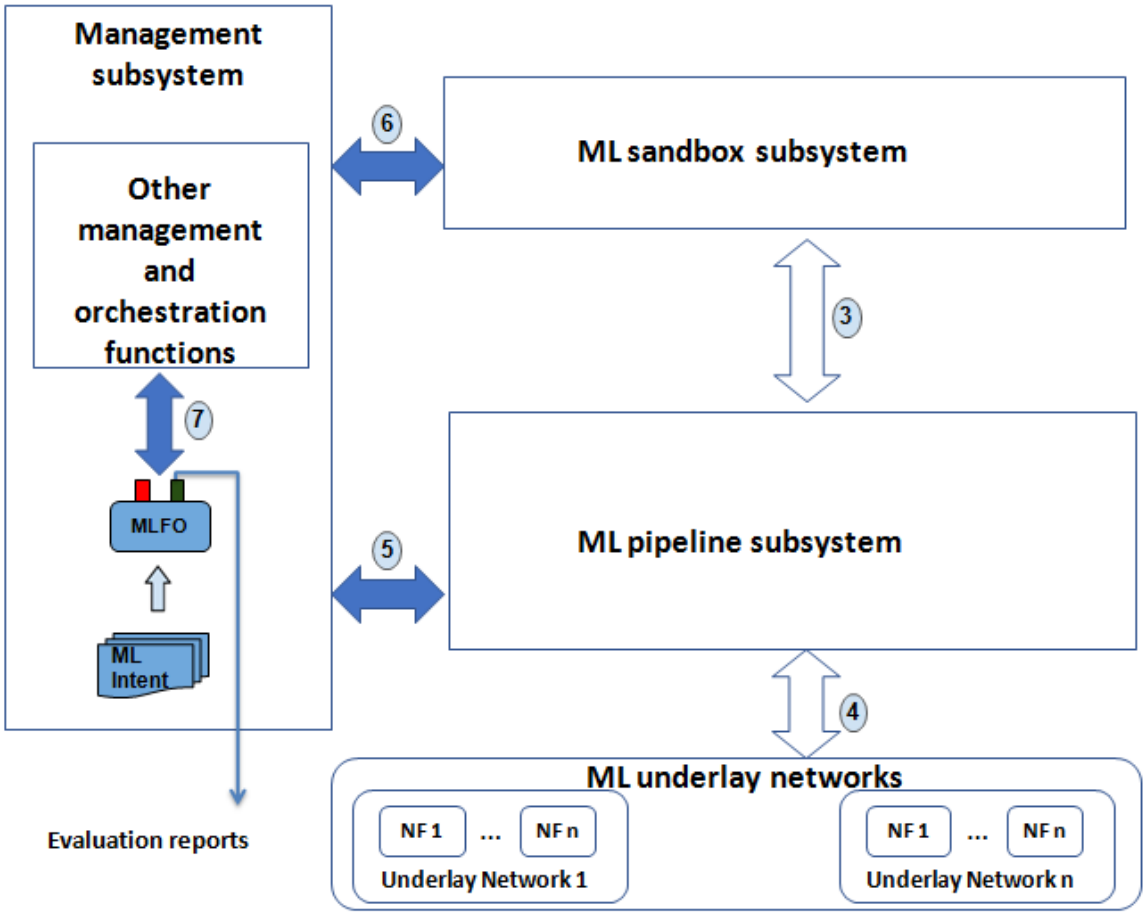

Figure 8-1 Architecture framework for evaluating intelligence level in the network

The reference points in figure 8-1 are described as below:

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

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

5, 6: The reference points between, respectively, Management subsystem and ML pipeline subsystem and ML sandbox subsystem are used for monitoring and evaluation of network intelligence level in the ML pipeline subsystem and the ML sandbox.

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

8.2 Architecture scenarios for network intelligence level

In this clause, the following architecture scenarios are considered: introduction of network services and query of network intelligence level. Figure 8-2 shows these two architecture scenarios. The major steps in the sequence chart are as below:

- Declarative specification of the ML underlay is made in ML Intent as defined in [ITU-T Y.3172]. This is input into the MLFO.

NOTE 1- Separately, the management subsystem may create the end-to-end network service.

- 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.
- ML pipeline nodes may send periodic or asynchronous reports to the MLFO on the Network intelligence level and performance.
- Based on the above reports, MLFO will respond to any query from the operator on the network intelligence level.

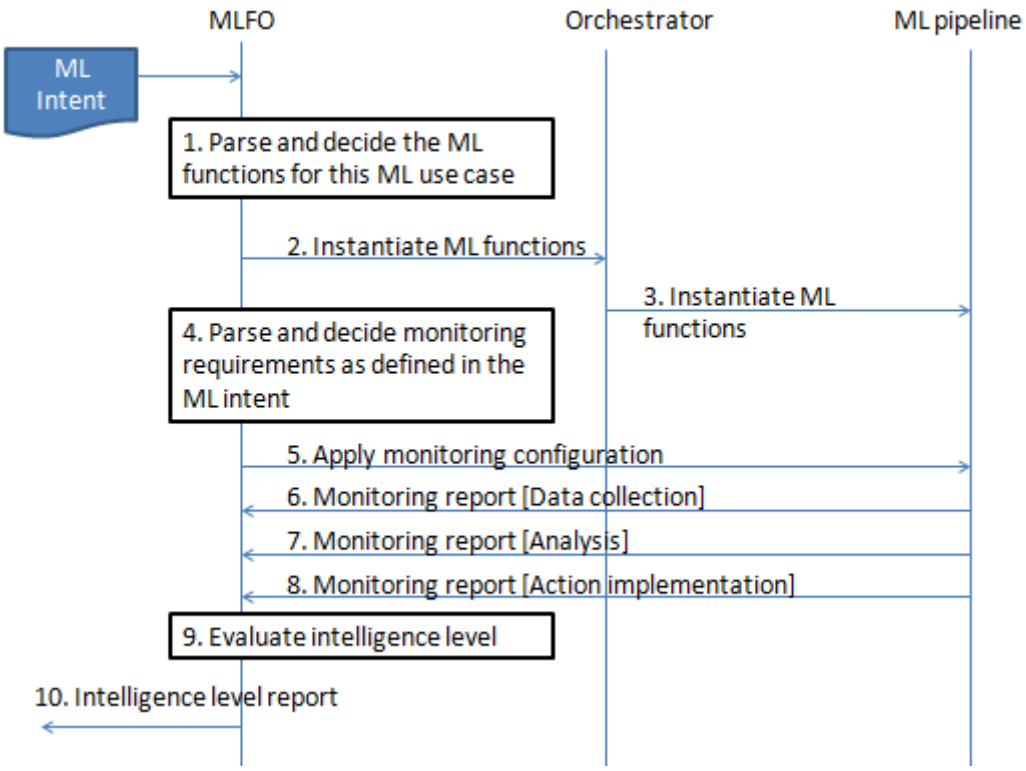

Figure 8-2 Architecture scenarios for network intelligence level

The steps in the sequence chart are as follows:

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

NOTE 2- 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: MLFO uses the 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 3- For example, data handling functions are instantiated along with the SRC and SINK.

4: 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 4- For example, the SINK needs to be queried to evaluate the network intelligence capability level of Action Implementation dimension supported by the ML underlay.

5: Monitoring configuration is applied to the ML pipeline.

NOTE 5- For example, the SINK is queried based on the above.

6: Monitoring report from SRC node in the ML pipeline is sent to MLFO regarding data collection. This may indicate specific dimensions and corresponding network intelligence capabilities.

NOTE 6- For example, SRC node gets the network intelligence capability level of Data Collection dimension from the NF which it is associated with. The monitoring report from the SRC reports the intelligence capability level of Data Collection dimension supported by the ML underlay for this use case.

7: Monitoring report from ML Model node of ML pipeline is sent to MLFO regarding analysis.

NOTE 7- For example, ML Model node gets the network intelligence capability level of Analysis dimension from the NF which it is associated with. The monitoring report from the ML Model node reports the network intelligence capability level of Analytics dimension supported by the ML underlay for this use case.

8: Monitoring report from SINK node of ML pipeline is sent regarding Action implementation.

NOTE 8- For example, SINK node gets the network intelligence capability level of Action Implementation dimension from the NF which it is associated with. The monitoring report from the SINK reports the network intelligence capability level of Action Implementation dimension supported by the ML underlay for this use case.

9: Based on the monitoring report from the ML pipeline nodes, network intelligence level is decided for this use case, using the method described in this Recommendation.

NOTE 9- For example, based on the report from the SINK, the network intelligence capability level of Action Implementation is decided, e.g., as level 2.

10: A report is produced for the operator or a query response is provided.

9. Security considerations

The security considerations specified in [ITU-T Y.3172] are also 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, relationship between the framework for evaluating network intelligence level in future networks including IMT-2020 described in this document and 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 also has 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 J3016 document [b-SAE J3016], clarifying the 6-level automatic driving rating standard (L0 ~ L5), which has become widely accepted and used by the automotive industry. The standard is shown in the table below.

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 perform all remaining aspects of the dynamic driving task.	Human driver and System	Human driver	Human driver	Some driving modes	1
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 perform 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	3/4
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).

This standard has been 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.

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 networks.

- 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 limited number of consumer segments.
- The end-user for the evaluation of intelligence level in automotive industry is the consumer and hence it is important to keep intelligence levels simple and easily understandable and comparable. End-users for telecom service providers, on the other hand, may have understanding of technical details about such comparison. Such evaluation needs to consider different technical domains and underlying service requirements.
- Telecom network architecture is much more complicated than the automotive design and hence telecom network intelligence level evaluation involves multi-dimensional aspects such as domains, use cases, workflows and services.

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 document, 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 document are:

- Ability to deploy new applications and services using open application programming interfaces (API), transferrable analytics solutions, need for operation agility and efficiency, lead to 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 has to 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 document, with a related TM Forum (TMF) document [b-TMF-AUTO].

The key points in [b-TMF-AUTO] which are relevant to the framework described in this document 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 & 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 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 document, 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-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 & 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 & 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 is issued by human (operator).

- Action Implementation: System

Rationale: System automatically execute 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 & System	Human & System	Human	Human	Human
L2	**Preliminary intelligence**	System	Human & System	Human & System	Human	Human
L3	**Intermediate intelligence**	System	System	Human & System	Human & System	Human
L4	**Advanced intelligence**	System	System	System	System	Human & System
L5	**Full intelligence**	System	System	System	System	System

Per-dimension network intelligence levels are assumed as shown above. 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 network coverage optimization has a level 2 (Preliminary Intelligence) overall network intelligence level.

Upgrading suggestions

To upgrade to the next network intelligence level, Data Collection needs to be completed automatically by the system according to system defined data collecting rules and Decision needs to be completed automatically by the system according to human 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 road blocks 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 will 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 & System

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

- Analysis: Human & 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-1 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 & System	Human & System	Human	Human	Human
L2	**Preliminary intelligence**	System	Human & System	Human & System	Human	Human
L3	**Intermediate intelligence**	System	System	Human & System	Human & System	Human
L4	**Advanced intelligence**	System	System	System	System	Human & System
L5	**Full intelligence**	System	System	System	System	System

Per-dimension network intelligence levels are assumed as shown above. 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 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 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 & 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 & 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 & 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-1 provides the result of the evaluation according to the above assumptions.

Table II-3 Evaluation of Network intelligence level on Alarm Root Cause Analysis 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 & System	Human & System	Human	Human	Human
L2	**Preliminary intelligence**	System	Human & System	Human & System	Human	Human
L3	**Intermediate intelligence**	System	System	Human & System	Human & System	Human

L4	**Advanced intelligence**	System	System	System	System	Human & System
L5	**Full intelligence**	System	System	System	System	System

Per-dimension network intelligence levels are assumed as shown above. 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 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 is at level 3 (Intermediate intelligence). To upgrade to the next level, Analysis and Decision 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 & System

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

- Analysis: Human & 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-1 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 & System	Human & System	Human	Human	Human
L2	**Preliminary intelligence**	System	Human & System	Human & System	Human	Human
L3	**Intermediate intelligence**	System	System	Human & System	Human & System	Human
L4	**Advanced intelligence**	System	System	System	System	Human & System
L5	**Full intelligence**	System	System	System	System	System

Per-dimension network intelligence levels are assumed as shown above. 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 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 should be improved accordingly. For example, to advance to Level 3 (Intermediate Intelligence), the Data Collection needs to be completed automatically by the system with system defined rules and Decision needs to be completed automatically by the system with human 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 & 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 & 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 & 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 non-busy 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-1 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 & System	Human & System	Human	Human	Human
L2	**Preliminary intelligence**	System	Human & System	Human & System	Human	Human
L3	**Intermediate intelligence**	System	System	Human & System	Human & System	Human
L4	**Advanced intelligence**	System	System	System	System	Human & System
L5	**Full intelligence**	System	System	System	System	System

Per-dimension network intelligence levels are assumed as shown above. 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 should be activated for analysis to advance to level 3 (Intermediate Intelligence). To further advance to level 4 (Advanced Intelligence), Analysis and Decision need to be automatically done by the system and service planning and deployment needs to be automated using pre-specified templates. For level 5 (Full Intelligence), intent-based service planning and deployment needs to be implemented.

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