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

Future networks

Functional framework for artificial intelligence-based network service provisioning in future networks including IMT-2020

Recommendation ITU-T Y.3178

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Recommendation ITU-T Y.3178

Functional framework for artificial intelligence-based network service provisioning in future networks including IMT-2020

Summary

Recommendation ITU-T Y.3178 specifies a functional framework for network service provisioning based on artificial intelligence (AI) in future networks, including international mobile telecommunication-2020 (IMT-2020). This Recommendation addresses the following aspects:

– a business role-based model for AI-based network service provisioning;

– high-level requirements for the roles and their interactions from an AI-based operational perspective;

– functional components and their interactions for AI-based operations for network service provisioning.

History

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Functional framework for artificial intelligence-based network service provisioning in future networks including IMT-2020

1 Scope

This Recommendation specifies a functional framework for network service provisioning based on artificial intelligence (AI) in future networks, including international mobile telecommunication-2020 (IMT-2020). This Recommendation addresses the following aspects:

– a business role-based model for AI-based network service provisioning;

– high-level requirements for the roles and their interactions from an AI-based operational perspective;

– functional components and their interactions for AI-based operations for network service provisioning.

NOTE – AI-based operations of network providers lie outside the scope of this Recommendation.

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.3101] Recommendation ITU-T Y.3101 (2018), *Requirements of the IMT-2020 network.*

[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 activity [b-ITU-T Y.3502]: A specified pursuit or set of tasks.

3.1.2 functional component [b-ITU-T Y.3502]: A functional building block needed to engage in an activity, backed by an implementation.

3.1.3 machine learning (ML) [ITU-T Y.3172]: Processes that enable computational systems to understand data and gain knowledge from it without necessarily being explicitly programmed.

NOTE 1 – This definition is adapted from [b-ETSI GR ENI 004].

NOTE 2 – Supervised machine learning and unsupervised machine learning are two examples of machine learning types.

3.1.4 machine learning model [ITU-T Y.3172]: Model created by applying machine learning techniques to data to learn from.

NOTE 1 – A machine learning model is used to generate predictions (e.g., regression, classification, clustering) on new (untrained) data.

NOTE 2 – A machine learning model may be encapsulated in a deployable fashion in the form of a software (e.g., virtual machine, container) or hardware component (e.g., IoT device).

NOTE 3 – Machine learning techniques include learning algorithms (e.g., learning the function that maps input data attributes to output data).

3.1.5 machine learning overlay [ITU-T Y.3172]: A loosely coupled deployment model of machine learning functionalities whose integration and management with network functions are standardized.

NOTE – A machine learning overlay aims to minimize interdependencies between machine learning functionalities and network functions using standard interfaces, allowing for the parallel evolution of functionalities of the two.

3.1.6 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].

3.1.7 machine learning underlay network [ITU-T Y.3172]: A telecommunication network and its related network functions which interfaces with corresponding machine learning overlays.

NOTE – An IMT-2020 network is an example of a machine learning underlay network.

3.1.8 network function [b-ITU-T Y.3100]: In the context of IMT-2020, a processing function in a network.

NOTE 1 – Network functions include but are not limited to network node functionalities, e.g., session management, mobility management, and transport functions, whose functional behaviour and interfaces are defined.

NOTE 2 – Network functions can be implemented on dedicated hardware or as virtualized software functions.

NOTE 3 – Network functions are not regarded as resources, but rather any network functions can be instantiated using the resources.

3.1.9 orchestration [b-ITU-T Y.3100]: In the context of IMT-2020, the processes aiming at the automated arrangement, coordination, instantiation and use of network functions and resources for both physical and virtual infrastructures by optimization criteria.

3.1.10 role [b-ITU-T Y.3502]: A set of activities that serves a common purpose.

3.1.11 sub-role [b-ITU-T Y.3502]: A subset of the activities of a given role.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI	Artificial Intelligence
API	Application Programming Interface
E2E	end to end
ICT	Information and Communication Technology
IMT-2020	International Mobile Telecommunication-2020
IoT	Internet of things
LAN	Local Area Network

ML Machine Learning

MLFO Machine-Learning Function Orchestrator

QoS Quality of Service

5 Conventions

In this Recommendation, requirements are classified as follows.

The phrase "is required to" indicates a requirement that must be strictly followed and from which no deviation is permitted if conformity to this Recommendation is to be claimed.

The phrase "is recommended" indicates a requirement that is recommended, but which is not absolutely required. Thus, this requirement need not be present to claim conformity.

The phrase "can optionally" indicates an optional requirement that 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 or service provider. Rather, it means the vendor may optionally provide the feature and still claim conformity with the specification.

In the body of this Recommendation and its annexes, the auxiliary verbal forms "shall", "shall not", "should" and "may" sometimes appear, in which case they are to be interpreted, respectively, as "is required to", "is prohibited from", "is recommended" and "can optionally". The appearance of such phrases or keywords in an appendix or in material explicitly marked as informative is to be interpreted as having no normative intent.

6 Introduction

Application services provided over future networks, including IMT-2020, will be configured and operated using diversified information and communication technology (ICT) infrastructure capabilities based on, e.g., cloud computing, edge computing and various types of networking technology. Each application service, e.g., provided in different vertical industries, such as manufacturing, transportation, medicine and agriculture, requires ICT capabilities for its business operation.

The mapping between the requirements of an application service and ICT infrastructure capabilities is essential for the delivery of future application services using ICT infrastructure capabilities in an effective and agile cooperation manner. This mapping can be quite complex to achieve, especially when application services are deployed over various networking domains – possibly operated and managed by different stakeholders – like access and core networks, and different types of network, such as mobile networks, sensor networks, local area networks (LANs) and data centre networks. Desirably, automatic or autonomous configuration and operation of such mapping is required to , consider the complexity caused by the diversity both in the application services and ICT infrastructure. AI including ML techniques is regarded as helpful for this mapping.

Network services provisioned by network providers in various technological and administrative domains are integrated as application service offerings. This Recommendation describes this integration by defining a business role model focusing on AI-based network service provisioning including interactions between business roles.

7 Business role-based model for network service provisioning

7.1 Business role-based model

There are multiple stakeholders who play business roles in network service provisioning, from application users to network providers. The ICT infrastructure capabilities from different providers,

possibly across multiple networking domains, are combined and integrated by an application service integrator, providing dedicated application services to application users.

NOTE – The application service integrator is equivalent to "application provider" in other contexts.

Figure 7-1 shows stakeholder business roles involved in network service provisioning. Four main roles are identified to enable network service provisioning: application user; application service integrator; communication provider; and network provider.

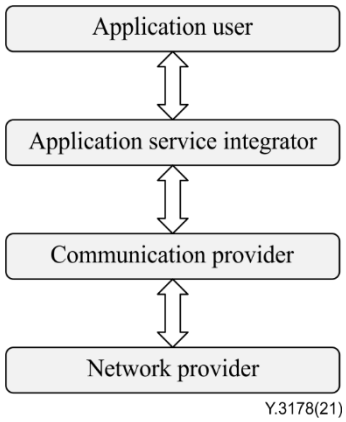

Figure 7-1 – Business roles in network service provisioning

The application service integrator offers specific application services to the application user. The application service integrator extracts the networking-related application user requirements and transforms them into communication service-specific requirements that need to be addressed by the underlying capabilities of a communication provider. In this context, the application service integrator is a user of communication services provided by potentially multiple communication providers and combines these communication services in a communication service accommodating the requirements of the user of the application service.

The communication provider offers communication services to the application service integrator. The communication provider extracts the networking-related application service integrator's communication service requirements and transforms them into network service-specific requirements that need to be addressed by the underlying network provider's capabilities. In this context, the communication provider is a user of network services provided by potentially multiple network providers and combines these network services in an end-to-end (E2E) network service accommodating the communication service requirements of the application service integrator.

This Recommendation essentially provides AI-based network service provisioning-related requirements and functional components with respect to application service integrator and communication provider roles. Network provider and application user roles lie outside the scope of this Recommendation.

7.2 Decomposition into sub-roles for AI-based network service provisioning

AI-ML techniques can help to mitigate the complexity of network service provisioning for diversified business environments. Each role shown in Figure 7-1 has the specific intelligence and data to optimize its capabilities.

Figure 7-2 shows the decomposition into sub-roles of the roles identified in Figure 7-1.

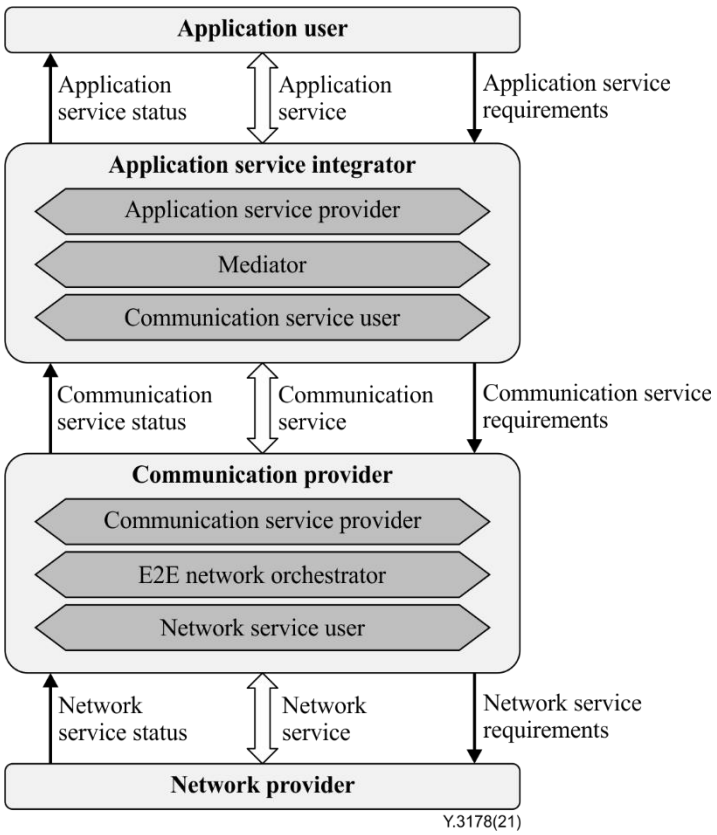

Figure 7-2 – Sub-role decomposition of network service provisioning

Information flows between the roles, as shown in Figure 7-2, are described in clause 7.3.

The application service integrator and the communication provider roles are decomposed into three sub-roles, namely those for: a provider; a user; and one that is AI-ML related.

Among the sub-roles in application service integrator and communication provider roles, only AI-ML-related sub-roles are considered in the scope of this Recommendation. The other sub-roles, related to providers and users, lie outside the scope of this Recommendation and their activities deal with interaction handling between roles.

NOTE 1 – The activities of the two identified AI-ML-related sub-roles, i.e., mediator and E2E network orchestrator, are performed and managed independently.

NOTE 2 – The application user and the network provider roles may also have AI-ML-related capabilities, even though they are not shown in Figure 7-2, as they lie outside the scope of this Recommendation.

7.2.1 Mediator

The mediator sub-role transforms the requirements of the application service into those of the communication service that need to be addressed by the underlying capabilities of the communication provider. Although the transformation is based on application service requirements received from each userapplication service requirements may not provide enough information for this activity to be effective.

The mediator sub-role utilizes various pieces of additional information, such as the resource usage trend of the application user and best practice, to satisfy the requirements of each application user'. The derived communication service requirements are transferred to the communication provider via the communication service user sub-role.

The mediator sub-role also uses communication service status information from the relevant communication provider to adjust the networking requirements while still fulfilling application service requirements. This adjustment is an iterative negotiation process between the communication

provider and the application service integrator. During this process, the two roles operate independently due to potentially different administrative policies and AI-ML objectives, possibly being played by separate business entities.

7.2.2 End-to-end network orchestrator

The E2E network orchestrator sub-role transforms communication service requirements into network service requirements that need to be addressed by the underlying capabilities of the network provider. Activities of the E2E network orchestrator sub-role include the design and management (creation, update, deletion, etc.) of E2E network services, i.e., services composed of one or more network services provided by network providers. The design activity specifies E2E network services including their configuration, while the management activity orchestrates E2E network services according to their design. As a result of these two activities, the E2E network orchestrator sends the resulting network service requirements to the network provider via the network service user sub-role.

The E2E network orchestrator sub-role also uses network service status information from the relevant network provider to adjust network service requirements while still fulfilling communication service requirements. This adjustment is an iterative negotiation process between the network and communication providers. During this process the two roles operate independently due to potentially different administrative policies and AI-ML objectives, possibly being played by separate business entities.

7.3 Information exchange between the roles

The information exchanged between the roles is summarized as follows.

Application service requirements: Requirements from application users are related to the concerns and environments of their businesses, and are usually represented in the form of intent [b-TF-WP-AN].

Communication service requirements: Requirements from the application service integrator relate to a network service whose detailed description matches the capabilities of a communication provider. Communication service requirements should be agnostic to underlying networking technologies.

Network service requirements: Requirements from the communication provider relate to the deployment and operation of network services by network providers involved in the network service. Network service requirements match network providers' capabilities.

Application service status: This information relates to the current status of the application services provided as feedback to the application user. This feedback may be used in the negotiation process to iteratively adjust application service requirements according to application service status.

NOTE 1 – Examples of information included in the feedback are faulty conditions and resource usage of the application service.

Communication service status: Th is information relates to the current status of the communication services provided as feedback to the application service integrator. This feedback may be used in the negotiation process to iteratively adjust communication service requirements according to communication service status.

NOTE 2 – Examples of information included in the feedback are faulty conditions and resource usage of the communication service.

Network service status: This information relates to the current status of the network services provided as feedback to the communication provider. This feedback may be used in the negotiation process to iteratively adjust network service requirements according to network service status.

NOTE 3 – Examples of information included in the feedback are faulty conditions and resource usage of the network service.

8 High-level requirements

8.1 Functional requirements

8.1.1 Application service integrator

REQ-ML-FUN-001	The application service integrator is required to support a function that automatically transforms the application service requirements from application users into communication service requirements that need to be addressed by communication providers according to their capabilities.
Description	The transformation is based on the application service requirements from application users. The requirements are usually represented in the form of intent [b-TF-WP-AN]. The generation of communication service requirements from this intent requires different levels of skill and this is further complicated by the diversity of business concerns of each application user. Moreover, application service requirements vary rapidly with change of business environment. AI-based automatic transformation is used to mitigate the gap between the incomplete, diversified or changing demands of each application user and the capabilities of the communication provider. Communication service requirements should be agnostic to networking technologies. Communication service requirements can also be satisfied by multiple communication providers based on their service coverage and capabilities.
Notes	NOTE 1 – The capabilities of the communication providerare expected to support standard communication service data models. NOTE 2 – If there are multiple communication providers, their capabilities may differ. NOTE 3 – The ML pipeline [ITU-T Y.3172] can be the basis of ML operation for the automatic transformation of requirements described here. NOTE 4 – The interpretation and processing of such requirements may trigger a negotiation cycle to best accommodate application service requirements with the capabilities of the communication provider.

REQ-ML-FUN-002	The application service integrator is required to support the description of communication service requirements considering a set of use cases.
Description	The application service integrator utilizes the description of use cases to classify application service requirements, which are used to achieve the transformation of the requirements.
Notes	NOTE – The transformation can be made efficient and flexible by the availability of standard models per application domain, e.g., vertical industries.

REQ-ML-FUN-003	The application service integrator is required to support infrastructure and technology agnostic application programming interfaces (APIs) exposed to application users.
Description	Application service requirements from users are mainly based on their business concerns. Based on technology agnostic APIs, application users can formulate their requirements so that matching communication providers can be used to achieve their business purposes in a timely and effective manner.
Notes	None.

REQ-ML-FUN-004	The application service integrator is recommended to support an interpretation function that captures application service requirements from users in the form of intent.
Description	The interaction between the user and service integrator of the application may be iterative because of the possible incompleteness of the declaration of application service requirements. Effective and standardized ways of information exchange may be necessary to achieve agile and accurate transformation of requirements.
Notes	NOTE – The intent can be presented as model-based templates or natural language.

REQ-ML-FUN-005	The application service integrator is recommended to improve transformation of application service requirements based on the learning of service usage patterns or prediction of the future needs of the application user.
Description	The application service integrator utilizes not only the requirements of the application user (e.g., intents), but also other information, including their usage patterns or trends. Furthermore, social and economic data, such as the business trends of the industry in which the user is involved, may be applicable to accommodate effective application service offerings.
Notes	None.

REQ-ML-FUN-006	The application service integrator is required to support the capability of service lifecycle management specific to each application user.
Description	The service lifecycle of the business operation of each application user may not be uniform. The timelines for service orders, negotiation, configuration, deployment, activation, redesign and deactivation of a particular application service are closely related to the business operation of the application user.
Notes	NOTE – Service lifecycle management integrates and optimizes processes such as service provisioning, service assurance, service fulfilment, service charging and service change management for particular workloads while respecting relevant governance and policies [b-ITU-T Y.3522].

REQ-ML-FUN-007	It is recommended that service lifecycle management not result in interruption of application services during the modification of application service requirements.
Description	Application service requirements vary according to the business situation of each user. Adaptation by the application service integrator to accommodate in-service modifications of service requirements while maintaining application service operational is desirable to achieve uninterrupted operation by the application user.
Notes	NOTE – In-service modification means application of configuration changes to the application services that are currently in operation.

REQ-ML-FUN-008	It is required that the service lifecycle management capability adapts the operation of the application service integrator at runtime based on events from communication providers.
Description	If the underlying communication services fail, the application service integrator adjusts the communication service requirements to recover from the situation. This could be possible by preparing an alternative solution with another set of communication service requirements to which to switch over, for example.
Notes	None.

8.1.2 Communication provider

REQ-ML-FUN-009	The communication provider is required to support a function that automatically designs the E2E network service along with its configuration, which satisfies the communication service requirements from the application service integrator according to the capabilities of the network provider.
Description	The communication service requirements from the application service integrator are unlikely to provide detailed network service requirements. AI-based automatic design can mitigate the gap between the communication service requirements and the capabilities of the network provider.
Notes	NOTE 1 – An ML pipeline [ITU-T Y.3172] responsible for AI-ML-based optimization of the E2E network service may be hosted in the communication provider. NOTE 2 – The involvement of multiple network providers in the E2E service design may raise design-time dependencies among network services, e.g., in terms of security and policy consistency. These issues need to be addressed by AI-based automatic design.

REQ-ML-FUN-010	The communication provider is required to utilize the APIs exposed by network providers.
Description	Network providers expose a set of standard, as well as provider-specific, APIs. Based on the APIs, the communication provider can formulate its requirements so that matching network providers can be used to achieve their service purposes in a timely and effective manner.
Notes	NOTE – Network providers may not support the full set of standardized APIs.

REQ-ML-FUN-011	The communication provider is required to support a function that manages E2E network services.
Description	The E2E network service required by the application service integrator usually consists of several network services (e.g., offering network, storage and computational resources) operated by network providers. Management of E2E network services includes their creation, update and deletion. When there is a dependency among network services, the order of executing management tasks should be respected. Otherwise, an error may occur. The communication provider is expected to have the capabilities to resolve this type of situation.
Notes	None.

REQ-ML-FUN-012	The communication provider is recommended to support an interpretation function that captures the communication service requirements from the application service integrator in the form of a declarative description.
Description	The interest of an application service integrator is only in the state of the communication service that is obtained after management (creation, update, deletion, etc.), but not in the management process itself. The communication service requirements may be represented as a desired state of the communication service in a declarative manner for the sake of simplicity. Effective and standardized data models for exchange may be necessary to achieve agile and accurate interpretation of requirements. Additionally, learning from standardized data models may be used to achieve AI-based optimization of E2E network service configuration.
Notes	None.

REQ-ML-FUN-013	The communication provider is recommended to accurately map communication service requirements to network service requirements by using additional information including the quality of E2E network service parameters.
Description	The communication provider utilizes not only communication service requirements, but also other information including the quality of E2E network service parameters (e.g., bandwidth, latency, and cost).
Notes	NOTE – Improvement of mapping from communication service requirements to network service requirements may be achieved by retraining and optimizing models in the ML sandbox [ITU-T Y.3172], which may include additional data, e.g., about the performance of trained models. The machine-learning function orchestrator (MLFO) may also be used to monitor and add further models.

REQ-ML-FUN-014	The communication provider is required to support the capability of service lifecycle management specific to each communication service user.
Description	The service lifecycle of business operation of each communication service user may not be uniform. The timelines for service ordering, negotiation, configuration, deployment, activation, redesign and deactivation of the system are closely related to the business operation of the communication service user.
Notes	None.

REQ-ML-FUN-015	It is recommended that the service lifecycle management not result in interruption of communication services during the modification of communication service requirements.
Description	The communication service requirements vary according to the situation of each application service integrator. Adaptation by the communication provider to accommodate in-service modifications of service requirements is desirable to achieve uninterrupted operation of the application service integrator.
Notes	NOTE – In-service modification means the action of applying configuration changes to network services that are currently at the execution stage.

REQ-ML-FUN-016	It is required that the service lifecycle management capability adapt the operation of the communication provider at runtime based on events from network providers.
Description	An example of underlying network events is a link failure in the infrastructure of an underlying network provider. The failover operation is possible by preparing an alternative network configuration and switching over to it, and may need to take into account timing requirements from the application service integrator.
Notes	NOTE 1 – Such a failover operation of the communication provider should be conducted without impacting the operations of the application service integrator. NOTE 2 – The failure may still be reported to the application service integrator in order to provide input for AI-based optimization.

8.2 Information exchange requirements

8.2.1 Between the application user and the application service integrator

REQ-ML-DAT-001	The application service integrator is required to support an information exchanging capability to negotiate iteratively the application service requirements with the application user.
Description	As the application service requirements are usually represented in the form of intent, the initially presented information by the application user may not be adequate to perform the transformation into communication service requirements. An interactive interface between the application user and the application service integrator is necessary for the accurate interpretation of the intent and the optimized formulation of the communication service requirements.
Notes	None.

8.2.2 Between the application service integrator and the communication provider

REQ-ML-DAT-002	The application service integrator and the communication provider are required to support an information exchange capability to match communication service requirements with the communication service configuration.
Description	Although communication service requirements are composed by the application service integrator, the communication service configuration that is applied should take into account various restrictions, such as effective availability of the resources of the network provider.
Notes	NOTE – Between communication service requirements and configurable communication services, there may be different types of mismatch, e.g., with respect to resource availability and networking functions supported. AI-ML models can be used to automate the matching of communication service requirements to the communication service configuration.

REQ-ML-DAT-003	The application service integrator and the communication provider are required to support the capability to exchange communication service status information, including fault and alarm indication.
Description	Failures are possible in the underlying infrastructures of the communication provider. The application service integrator may be informed of such situations, and advise its application users of possible actions to be taken.

	The contents and frequency of the information exchange may be set through the negotiation between the application service integrator and the communication provider, where possible. However, asynchronous information exchange caused by abnormal conditions is also supported. The information exchange caused by abnormal conditions may vary based on the business perspective of the application user.
Notes	NOTE – AI-ML models can be used to automate transformation of the communication service status into the application service status.

8.2.3 Between the communication provider and the network provider

REQ-ML-DAT-004	The communication provider and the network provider are required to support information exchange capability to match network service requirements with the network service configuration.
Description	The network service is based on the requirements designed by the communication provider. However, the network configuration that is applied should take into account various restrictions, such as the resources available from a network provider.
Notes	NOTE – Between the network service requirements and the configurable network services provided by the network provider, there may be different types of gap, e.g., related to resource availability and supported networking functions. The information exchange capability for such complex coordination to bridge the gaps is automated using AI-ML.

REQ-ML-DAT-005	The communication provider and the network provider are required to support the capability to exchange network service status information, including fault and alarm indication.
Description	Failures are possible in the underlying infrastructures of the network provider. The communication provider may be informed of such situations, and advise its communication service users of possible mitigation actions. The contents and frequency of the information exchange may be set through negotiation between the communication provider and the network provider, where possible. However, asynchronous information exchange caused by abnormal conditions is also supported. The information exchange caused by abnormal conditions may vary based on the communication provider's business perspective.
Notes	NOTE – AI-ML models can be used to automate transformation of the network service status into the communication service status.

9 Functional components and their interactions

The business roles and sub-roles described in clause 7 can be classified into two categories, namely user-provider-related roles and AI-ML-related ones. This clause describes the functional components of AI-ML-related roles and their interactions.

The activities of the two identified AI-ML related sub-roles, i.e., mediator and E2E network orchestrator, are performed and managed independently.

9.1 Mediator

The activities of the mediator sub-role include the matching of the intent expressed by the application user into corresponding communication service requirements.

Figure 9-1 shows the functional components and information flows in support of the activities of the mediator sub-role.

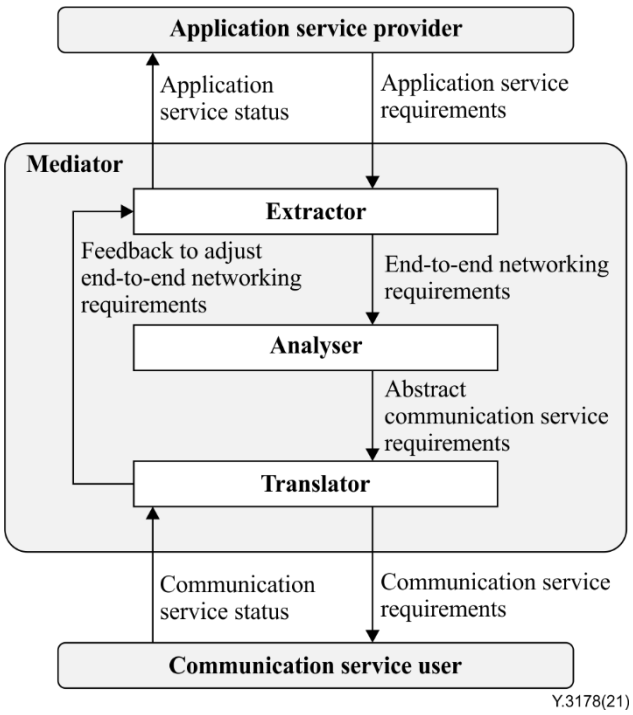

Figure 9-1 –Functional components and information flows of the mediator sub-role

The functional components of the mediator sub-role are as follows.

– Extractor: extraction and validation of the networking requirements as a part of the application service requirements received from the application service provider.

– Analyser: generation of abstract communication service requirements by analysing the networking requirements received from the extractor. The generated abstract communication service requirements are agnostic to technologies and implementation.

– Translator: translation of abstract communication service requirements into concrete ones specific to the underlying communication providers, i.e., matching APIs provided by the underlying communication providers.

NOTE – The abstract communication service requirements are internal to the application service integrator and are agnostic to the underlying communication provider. Taking bandwidth as an example of abstract service requirement of bandwidth, the corresponding concrete communication service requirements may be expressed by parameters in the APIs of the communication provider. Concrete communication service provisioning may also need additional parameters like identity credentials.

9.1.1 Extractor

The extractor functional component derives the networking requirements from application service requirements of the application user, relayed by the application service provider sub-role.

The networking requirements are derived based on the overall characteristics of the application user's environment, including traffic volume, geographical distribution of access points, the capability of endpoint devices and the network connectivity between the endpoint devices. The extractor derives the networking requirements, both functional and non-functional. The functional requirements are related to the functional aspects of network connectivity between the endpoint devices, such as bandwidth and network quality of service (QoS). The non-functional requirements are related to criteria that can be used to assess connectivity from various aspects, including availability, scalability, security and maintainability.

The extractor examines the application service requirements received from the application service provider and checks their validity, e.g., integrity, and types and ranges of values. The extractor

provides feedback to the application service provider through application service status so that the application service provider can adjust application service requirements. The derivation of networking requirements from application service requirements of the application user may use AI-ML techniques. Besides traffic characteristics and QoS parameters, the AI-ML function inside the extractor may take into account information from the application user, such as non-functional requirements.

9.1.2 Analyser

The analyser handles the networking requirements and derives a set of abstract communication service requirements, both functional and non-functional, that are optimized for the networking requirements. The abstract communication service requirements are an abstract view of networking capabilities, and are agnostic to technologies and implementation. The abstract communication service requirements concern aspects, such as logical network topology (including logical network links and logical network nodes), traffic performance, system availability and operational cost.

Since there may be gaps between the derived abstract communication requirements and the capabilities offered by underlying communication providers, coordination between the analyser and underlying communication providers may be necessary to mitigate the gaps. The coordination process matches the networking requirements with the capabilities and adjusts the networking requirements accordingly.

The derivation and coordination process may be automated, considering the diverse and extensive spectrum of application service requirements.

9.1.3 Translator

The translator translates abstract communication service requirements into communication service requirements to adapt to the capabilities of the underlying communication provider. The translated communication service requirements are composed of diverse requirements such as those related to service level agreements, capabilities of logical network nodes and redundancy.

While the translator performs operations as mentioned in the previous paragraph, specific communication service requirements cannot always be satisfied by the relevant communication provider, e.g., for service availability reasons. In this case, based on the communication service status information from the relevant communication provider, the feedback loop from the translator to the extractor is used so that the extractor can adjust the networking requirements while still fulfilling the application service requirements. The result of negotiation is notified to the application user via the application service provider sub-role.

9.2 E2E network orchestrator

The activities of the E2E network orchestrator sub-roleinclude the design and management of the E2E network services for each application user over the relevant network providers.

Figure 9-2 shows the functional components and information flows in support of the activities of the E2E network orchestrator sub-role.

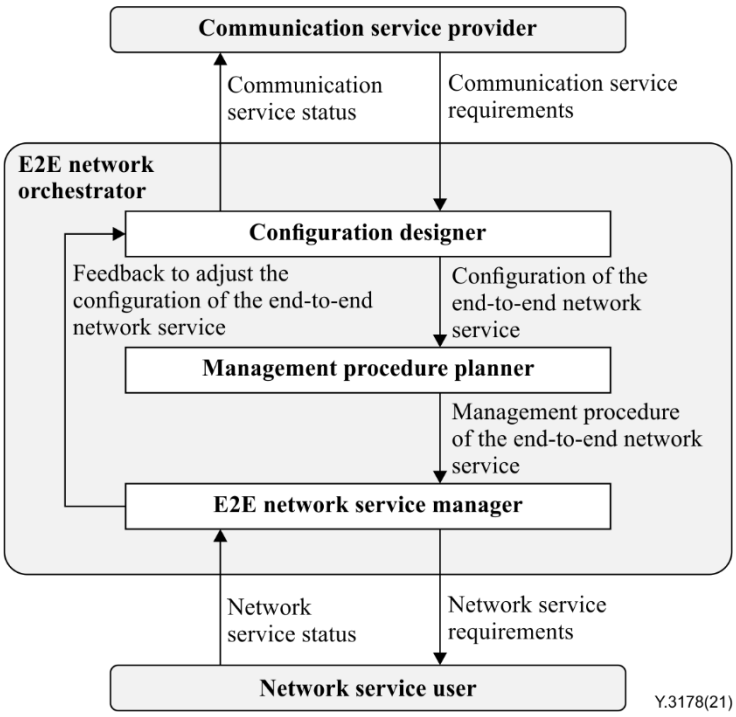

Figure 9-2 –Functional components and information flows of the end-to-end network orchestrator

The functional components of the E2E network orchestrator sub-role are as follows.

– Configuration designer: design of an E2E network service configuration from the communication service requirements.

– Management procedure planner: generation of a management procedure for E2E service, respecting the dependencies among network services requirements, from the E2E network service configuration.

– E2E network service manager: management of the E2E network service by executing the management procedure.

9.2.1 Configuration designer

The configuration designer receives the communication service requirements from the communication service user, relayed by the communication service provider, and generates an E2E network configuration that satisfies the communication service requirements. The communication service requirements include those for network connectivity and others related to performance and reliability.

The configuration designer generates a configuration of the E2E network service by composing the specific network services over the relevant network providers into the E2E network service appropriately. Each configuration of the E2E network service is derived from a large number of candidate configuration patterns in order to respond to a variety of communication service requirements flexibly. The candidate configuration patterns may be generated using configuration templates provided by network providers.

The complexity in designing the E2E network configuration in real time can be alleviated by picking an appropriate configuration from the candidate configuration patterns using AI-ML capabilities, which are used in the configuration designer to address the complexity of searching and selection for an appropriate configuration. The configuration designer hosts the ML pipeline [ITU-T Y.3172] responsible for AI-ML based optimization of the E2E network service.

The configuration designer may receive feedback from the E2E network service manager notifying that the configuration cannot be satisfied by the relevant network providers, then the configuration designer may redesign the configuration to resolve the discrepancy. This process is repeated until the negotiation is concluded.

NOTE – The detailed mechanisms of the configuration pattern design, including – but not limited to – generation and selection of candidate configuration patterns and negotiation between configuration designer and relevant network providers, are outside the scope of this Recommendation.

9.2.2 Management procedure planner

The management procedure planner receives the E2E network configuration from the configuration designer and generates the management procedure of the E2E network service as an ordered list of network service requirements. The E2E network configuration includes the description of specific network services and relationships (implying dependencies) between the network services as in a typical declarative description of network configuration.

9.2.3 E2E network service manager

The E2E network service manager receives the management procedure of the E2E network service from the management procedure planner and executes the procedure. The network service requirements in the procedure may be implemented as API calls to the relevant network providers.

While executing the procedure, the network service requirements cannot always be satisfied by the relevant network providers, e.g., for service availability reasons. In this case, based on the network service status information from the relevant network providers, the E2E network service manager provides feedback to the configuration designer, who can adjust the configuration of the E2E network service while still fulfilling the communication service requirements. The adjustment result is notified to the communication service provider.

10 Security considerations

General network security requirements of IMT-2020 specified in [ITU-T Y.3101], together with security requirements specified for a high-level architecture framework for ML in future networks including IMT-2020 [ITU-T Y.3172] are applicable.

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