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

Future networks

AI enabled cross-domain network architectural requirements and framework for future networks including IMT-2020

Recommendation ITU-T Y.3115

ITU-T

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Recommendation ITU-T Y.3115

AI enabled cross-domain network architectural requirements and framework for future networks including IMT-2020

Summary

Recommendation ITU-T Y.3115 addresses the problem of lack of an architecture to coordinate the artificial intelligence (AI) capabilities among the current network domains, and specifies architectural requirements and framework of AI enabled cross-domain networks for future networks including IMT-2020, which aim to achieve overall network intelligence.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Architectural framework, artificial intelligence, closed loop, cross-domain network, design principles, future networks, IMT-2020, requirements.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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AI enabled cross-domain network architectural requirements and framework for future networks including IMT-2020

1 Scope

This Recommendation specifies architectural requirements and framework of artificial intelligence (AI) enabled cross-domain networks for future networks including IMT-2020.

This Recommendation addresses the following topics:

– Introduction and design principles;

– Architectural requirements;

– Architectural framework.

2 References

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

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

[ITU-T Y.3176] Recommendation ITU-T Y.3176 (2020), *Machine learning marketplace integration in future networks including IMT-2020*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 domain [b-ITU-T G.8081]: A domain represents a collection of entities that are grouped for a particular purpose.

3.1.2 functional abstraction [b-ETSI GS ZSM 002]: The ability to generalize the behaviour of related entities, allowing to encapsulate details of multiple variants of those entities into a single one.

3.1.3 IMT-2020 [b-ITU-T Y.3100]: Systems, system components, and related technologies that provide far more enhanced capabilities than those described in [b-ITU-R M.1645].

NOTE – [b-ITU-R M.1645] defines the framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000 for the radio access network.

3.1.4 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.

3.1.5 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.

3.1.6 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).

3.1.7 mobile network [b-ITU-T Q.1762]: A network that provides wireless access to its services and supports mobility.

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 a 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.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 closed loop: A type of control mechanism in which the outputs and behaviour of a system are monitored and analysed, and the behaviour of the system is adjusted so that improvements may be achieved towards definable goals.

NOTE 1 – Observe, Orient, Decide and Act (OODA) [b-OODA], MAPE-K [b-MAPE-K] are examples of closed loop mechanism.

NOTE 2 – Examples of definable goal types are optimization of network resources' utilization and automated service fulfilment and assurance. Goals may be defined using declarative mechanisms.

NOTE 3 – The system may consist of a set of managed entities, workflows and/or processes in a network.

3.2.2 data services: Services that provide authorized consumers with the capabilities of collecting, processing, retrieving and sharing data within a single domain and across domains.

3.2.3 inference services: Services that provide authorized consumers with the capabilities of inference based on the artificial intelligence/machine learning models and data within a single domain and/or across domains.

NOTE – Inference capabilities include, but are not limited to, prediction, classification, analysis and decision-making based on artificial intelligence technologies.

3.2.4 machine learning function orchestrator (MLFO) services: Services that provide authorized consumers with the capabilities of machine learning function orchestrator.

NOTE – In the context of this Recommendation, and in line with [b-ITU-T Y.3174], [ITU-T Y.3176] and [b-ITU-T Y.3179], machine learning function orchestrator services can be used for orchestrating data services, training services and inference services.

3.2.5 training services: Services that provide authorized consumers with the capabilities of training artificial intelligence models within a single domain and/or across domains.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI	Artificial Intelligence
KPI	Key Performance Indicator
ML	Machine Learning
MLFO	Machine Learning Function Orchestrator
O&M	Orchestration and Management
QoS	Quality of Service
SBI	Service Based Interface
SLA	Service Level Agreement

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.

In this Recommendation, services defined as data services, training services, inference services and machine learning function orchestrator (MLFO) services, generally qualify as AI services.

6 Introduction

Networks continue to evolve and become more flexible with the introduction of technologies such as network slicing, and programmable networks. However, increasing network flexibility also means increasing management complexity. The industry is currently paying great attention to the evolution of communication functions and information transmission, and there is a relatively mature ecosystem. In order to use the increased flexibility of the network to meet demand goals, the industry is also paying more attention to the whole network analysis including the use of artificial intelligence (AI)/machine learning (ML) technologies.

The IMT-2020 network is comprised of domains with different functionalities, including access network domain, core network domain, transport network domain, network management domain, network service orchestration and management domain, and business management domain. Each domain has functionalities independent from the other domains, but it also interacts with other domains (cross-domain collaboration functionalities). Cross-domain collaboration is essential in order to enable overall network intelligence.

A number of standardization organizations or groups are specifying requirements, frameworks, architectures and solutions according to their respective responsibilities. However, the current specifications do not adequately address functionalities to achieve cross-domain coordination and integration of artificial intelligence capabilities in different network domains.

This Recommendation addresses the problem of lack of an architecture to coordinate artificial intelligence capabilities among the current network domains, and specifies cross-domain network architectural requirements and framework which aim to achieve an AI enabled cross-domain network for future networks including IMT-2020.

7 Design principles

The design goal of AI enabled cross-domain network architectural framework is to support an AI enabled network which can realize inter-domain collaboration while preserving intra-domain autonomy. This clause specifies the principles applicable for the design of an AI enabled cross-domain architectural framework.

The design principles are as follows:

1) Single domain operational independence

This principle enables the operational independence of each IMT-2020 network domain. As an example, the configuration parameters of a core network domain can be optimized according to the results of the closed loops internal to the core network domain, without interaction with other domains.

2) Cross-domain collaboration

This principle enables the support of collaboration among different IMT-2020 network domains using more than one AI service. For example, when the data services, training services or inference services in a single domain cannot satisfy a request from a service consumer, cross-domain collaboration can be involved.

3) Automation

This principle enables each IMT-2020 network domain to support automated functionalities, i.e., minimizing manual intervention. This principle can be applied, but is not limited to, management and orchestration.

4) Functional abstraction

This principle enables an IMT-2020 network domain to deal with the realization of its internal functions, while shielding the functions' complexity externally. Functional abstraction is seen as an essential principle to be supported in case of cross-domain collaboration.

5) Distributed intelligence

This principle enables the deployment of intelligence in entities of different domains of the IMT-2020 network.

NOTE – The deployment of intelligence in entities at the edge of the IMT-2020 network can be critical for service consumers at the edge.

6) Sharing of collected data

This principle enables the usage of data collected in a domain by multiple AI services within the domain or across domains. This principle can be applied in case of single domain or cross-domain closed loops.

7) Privacy and security

This principle ensures that regulation and policies related to data privacy and security are followed as appropriate. For example, this principle is applied when sharing data across domains.

8 Architectural requirements

This clause describes the requirements for AI enabled cross-domain network architectural framework based on the principles identified in clause 7.

8.1 Requirements for single domain and cross-domain closed loops

The AI enabled cross-domain network architectural framework is required to support single domain and cross-domain closed loops.

NOTE – With the assistance of AI capabilities, closed loops can support AI services based on functional abstraction, as well as on cross-domain collaboration.

8.2 Requirements for data collection

The AI enabled cross-domain network architectural framework is required to support the collection of data from different domains.

NOTE – Examples of different types of data include signalling information, traffic flows, logs, configurations.

The AI enabled cross-domain network architectural framework is required to support deduplication of redundant data collected from different domains.

The AI enabled cross-domain network architectural framework is required to support real-time and offline data collection from different domains.

8.3 Requirements for data storage

The AI enabled cross-domain network architectural framework is required to support data storage of different data types, such as structured data and unstructured data.

The AI enabled cross-domain network architectural framework is required to support distributed data storage in different domains.

8.4 Requirements for data processing

The AI enabled cross-domain network architectural framework is required to support data processing which can be provided for a single domain or across domains.

Data processing includes data cleaning, data aggregation, data association and data labelling.

NOTE 1 – Data cleaning refers to the deletion of irrelevant data and duplicated data in the original data set, the smoothing of the noise data, and the processing of missing values and outliers [b-ITU-T X.1217].

NOTE 2 – Data aggregation refers to the integration of raw data according to requirements, such as data of the same session and/or the same user and/or the same time period.

NOTE 3 – Data association refers to the integration of relevant data from different collection points and collection times according to requirements.

NOTE 4 – Data labelling refers to the labelling of the training data according to the machine learning training requirements.

8.5 Requirements for AI service exposure

The AI enabled cross-domain network architectural framework is required to support standard interfaces to expose AI services within a single domain or across domains (i.e., AI services applied across multiple domains).

8.6 Requirements for collaborative training

The AI enabled cross-domain network architectural framework is required to support distributed collaborative training within a single domain or across domains (e.g., support of federated learning [b-FL]).

The AI enabled cross-domain network architectural framework is required to support distributed transfer training within a single domain or across domains (e.g., support of transfer learning [b-TL]).

8.7 Requirements for security and privacy

The AI enabled cross-domain network architectural framework is required to support access control for data repository within a single domain or across domains (i.e., data services applied across multiple domains).

The AI enabled cross-domain network architectural framework is required to support access control for AI services within a single domain or across domains (e.g., support of AI services across multiple domains).

The AI enabled cross-domain network architectural framework is required to support encrypted transport of private data across domains and encrypted storage of private data within each domain.

The AI enabled cross-domain network architectural framework is required to support detection and prevention of illegal access and attack within each domain.

The AI enabled cross-domain network architectural framework is required to support data privacy protection capabilities within a single domain or across domains (i.e., data services applied across multiple domains).

9. Architectural framework

9.1 Architectural framework overview

9.1.1 Functional layering

The functional layering of AI enabled cross-domain network architectural framework, as shown in Figure 9-1, comprises of four functional layers: the network function layer, the network management layer, the network service orchestration and management (O&M) layer and the business management layer.

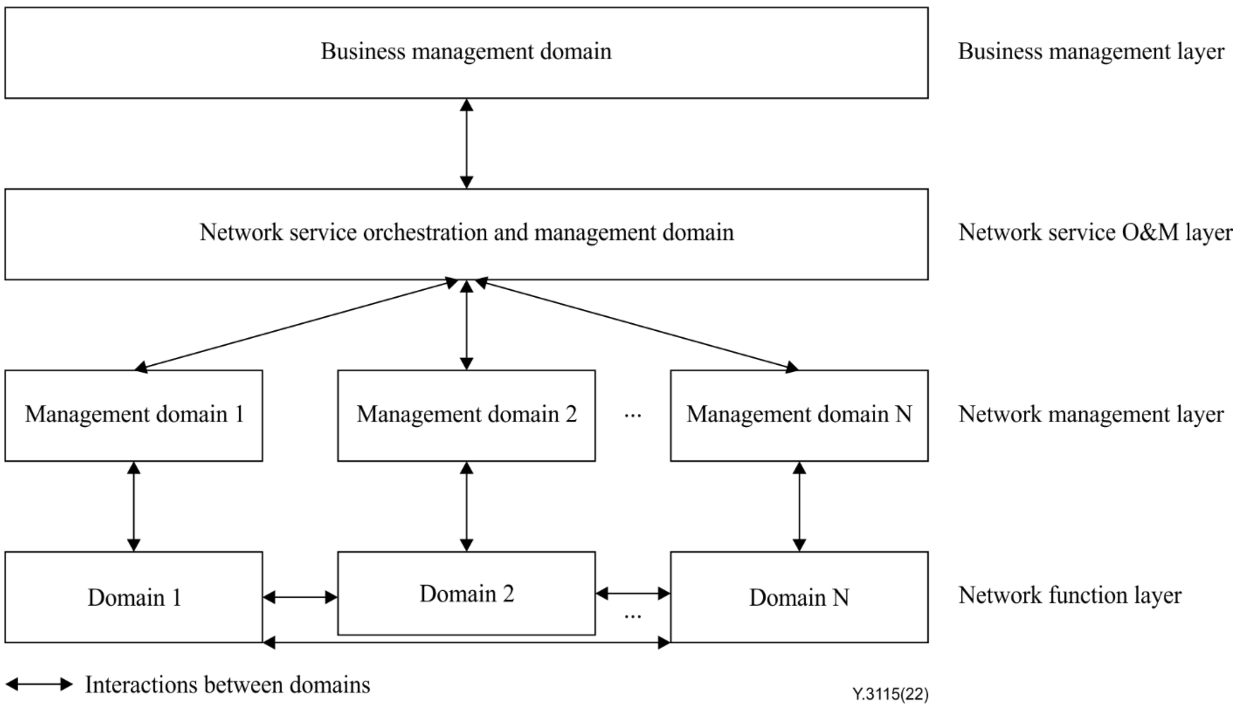

Figure 9-1 – Functional layering

Each functional layer includes one or more domains with their own scope and goals.

NOTE – Although not shown in Figure 9-1, multiple domains may exist in the network service orchestration and management layer and in the business management layer.

The interfaces between different layers in Figure 9-1 are bi-directional. The interactions through these interfaces include network information reporting from lower layer to upper layer, network operation instructions from upper layer to lower layer and AI service bidirectional interactions.

This framework aligns with the design principles identified in clause 7.

– The network function layer addresses network connectivity and network functions. The network function layer may include multiple network domains, e.g., access network domain, transport network domain and core network domain.
– The network management layer addresses network domain specific management. The network management layer may include multiple network management domains, e.g., access network management domain, transport network management domain and core network management domain.
– The network service orchestration and management layer addresses end-to-end network service orchestration and management.
– The business management layer addresses business service level management. The business management layer receives users' requirements and translates them to network service orchestration and management requirements which are then decomposed by the network management layer to configurations for the network function layer.

9.1.2 Closed loops

A closed loop, in line with the definition provided in clause 3, is a type of control mechanism in which the outputs and behaviour of a system are monitored and analysed, and the behaviour of the system is adjusted so that improvements may be achieved towards definable goals.

Closed loops are realized by functionalities within each domain (internal closed loops) as well as across domains (cross-domain closed loops) between adjacent layers or non-adjacent layers.

Each domain may host one or more closed loops (one or more internal closed loops or, partially, one or more cross-domain closed loops).

9.1.2.1 Internal closed loops

Figure 9-2 shows a view of the AI enabled cross-domain network architectural framework with internal closed loops.

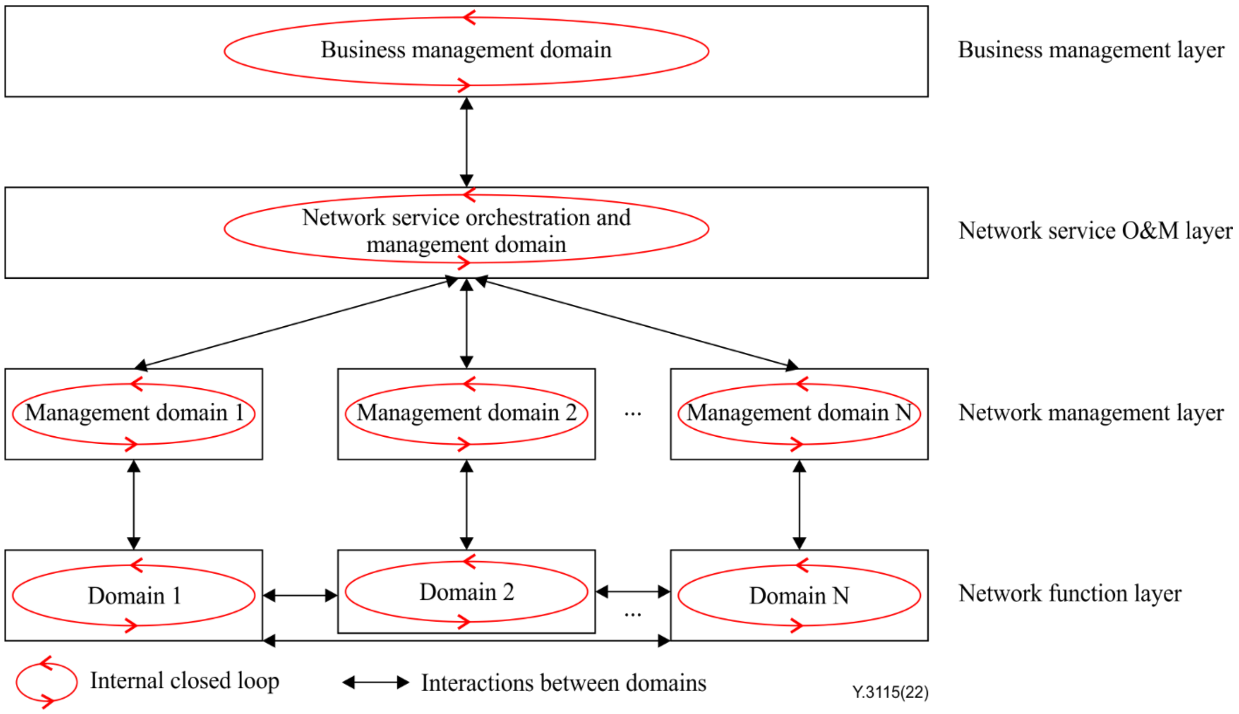

Figure 9-2 – View of the architectural framework with internal closed loops

The following provides example use cases of internal closed loops for the various layers:

– for the network function layer, congestion control mechanisms can be realized by closed loops with the assistance of automation and AI;

– for the network management layer, network failure detection and recovery mechanisms can be realized by closed loops with the assistance of automation and AI;

– for the network service orchestration and management layer, network slice performance analysis and optimization mechanisms can be realized by closed loops with the assistance of automation and AI;

– for the business management layer, user service experience analysis and optimization mechanisms can be realized by closed loops with the assistance of automation and AI.

9.1.2.2 Cross domain closed loops

9.1.2.2.1 Cross-domain closed loops between adjacent layers

Figure 9-3 shows a view of the AI enabled cross-domain network architectural framework with cross-domain closed loops between adjacent layers.

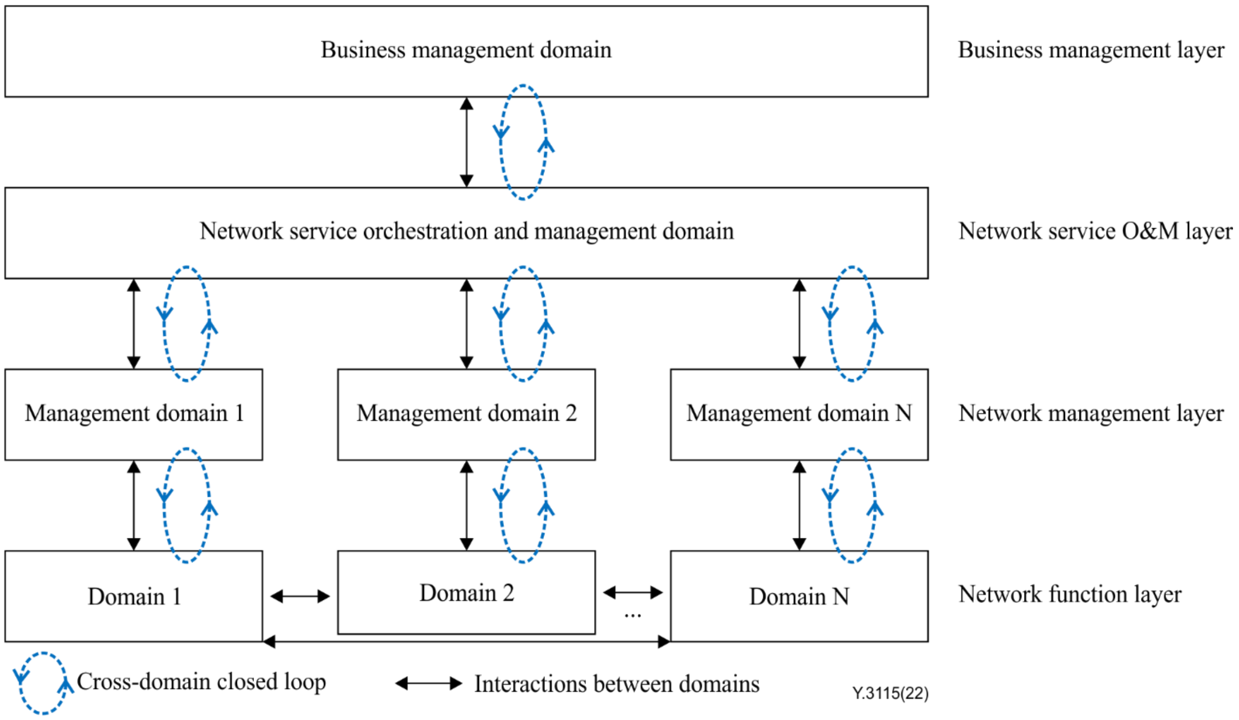

Figure 9-3 – View of the architectural framework with cross-domain closed loops between adjacent layers

The following provides example use cases of cross-domain closed loops for the various combinations of adjacent layers:

– for the cross-domain loops between network function layer and network management layer, the network failure root cause analysis mechanism can be realized by closed loops with the assistance of automation and AI. At the network function layer, key performance indicators (KPI) of network functions can be monitored and abnormal indicators can be detected based on AI services. The analysis result at the network function layer can be used in the network management layer;

– for the cross-domain loops between network management layer and network service management and orchestration layer, the network slice orchestration optimization mechanism can be realized by closed loops with the assistance of automation and AI. At the network management layer, performance analysis of network slices can be provided based on AI services. The analysis result at the network management layer can be used in the network service management and orchestration layer;

– for the cross-domain loops between network service management and orchestration layer and business management layer, the network slice service level agreement (SLA) translation and optimization mechanism can be realized by closed loops with the assistance of automation and AI.

NOTE – As an implementation example of this mechanism, the GSMA general slice template [b-GSMA-NG.116] is used as the SLA information for the communication between network slice customer and network slice provider. This information is translated into network attribute parameters and used as input to network resource model [b-3GPP TS 28.541].

9.1.2.2.2 Cross-domain closed loops between non-adjacent layers

Figure 9-4 shows a view of the AI enabled cross-domain network architectural framework with cross-domain closed loops between non-adjacent layers.

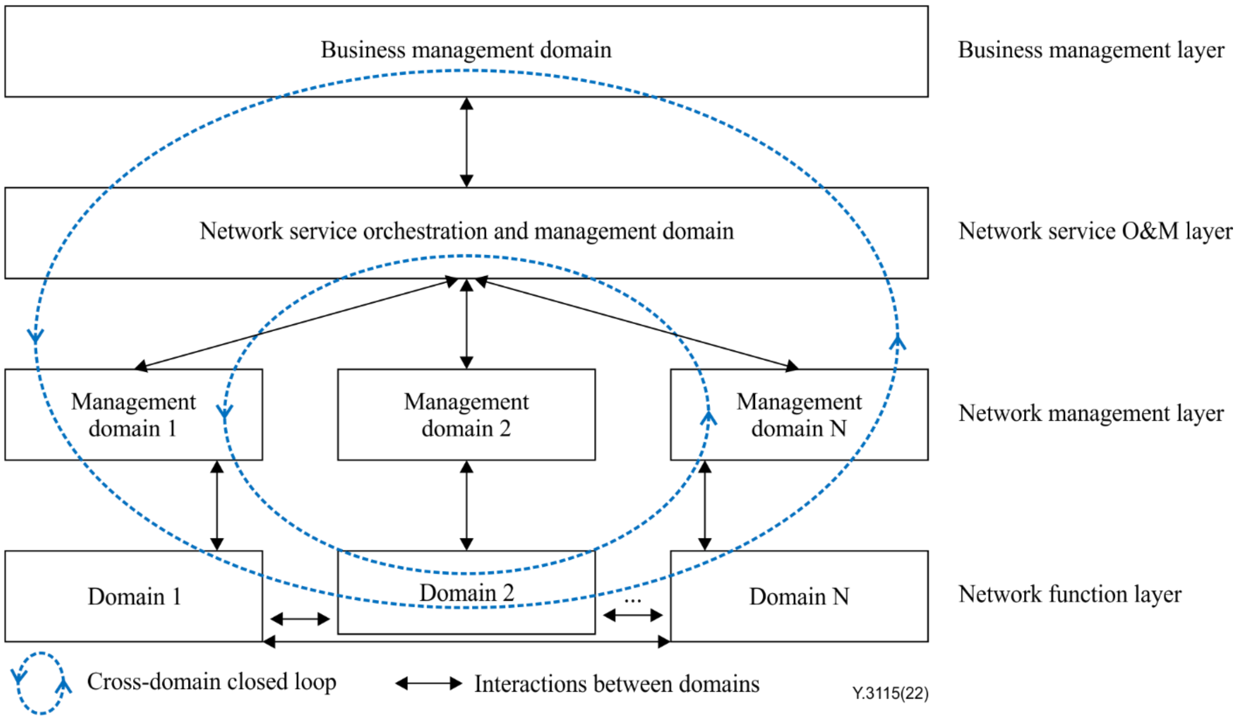

Figure 9-4 – Cross-domain closed loops among non-adjacent layers view of AI enabled cross-domain network architectural framework

NOTE 1 – The closed loops shown in Figure 9-4 are examples shown for illustrative purposes. A cross-domain closed loop can span over one or more domains in the involved layers.

The following provides example use cases of cross-domain closed loops for the various combinations of non-adjacent layers:

– For the cross-domain loops between network function layer and business management layer, the network slice SLA assurance mechanism can be realized by closed loops with the assistance of automation and AI. The following describes this use case from the perspective of each involved layer.

  - At the business management layer, based on AI services, the network slice SLA indicator can be monitored and predicted in the next period of time, and the SLA satisfaction can be determined. When the SLA requirements cannot be met, the reasons for the failure to meet requirements need to be analyzed. The analysis request is sent to the network service orchestration and management layer.
  - At the network service orchestration and management layer, upon reception of the analysis request, based on AI services, the network slice performance indicator is analyzed. If the analysis results show that a bandwidth bottleneck is the main reason, the domain which caused the bandwidth bottleneck needs to be determined. The analysis request is sent to the network management layer.
  - At the network management layer, upon reception of the analysis request, based on AI services, the management domain(s) analyzes if there are indications of throughput bottlenecks. As an example, if there was a link congestion, the management domain(s) may not be able to determine the causes of the congestion. In that case, the analysis request is sent to the network function layer.
  - At the network function layer, upon reception of the analysis request, based on AI services, the function domain(s) analyzes the network performance. As a follow up of the example mentioned at the network management layer, the performance indicators of the related links are analyzed, and it is evaluated whether the overall link performance is insufficient or network resources utilization is unbalanced. Finally, the

analysis results are propagated back up to the business management layer through all the involved layers.

NOTE 2 – Through the layer-by-layer propagation of the analysis results, policy adjustment decisions are made and executed at all layers. As examples, policy adjustments may be quality of service (QoS) adjustments for users and packet routing adjustments.

– For the cross-domain loops among network function layer and network service orchestration and management layer, the network slice performance guarantees mechanism can be realized by closed loops with the assistance of automation and AI. Similar to the previous use case, the three involved layers jointly realize the closed loop: the network service orchestration and management layer provides network slice performance analysis; the network management layer provides throughput analysis; the network function layer provides network performance analysis and its results propagate back to the network service orchestration and management layer through the network management layer.

NOTE 3 – Closed loops consisting of various combinations of non-adjacent layers for the business management layer, network service orchestration and management layer, and network management layer may exist, but are not discussed in this Recommendation.

9.2 Domain functionalities

Figure 9-5 shows an example of domain functionalities and interactions.

NOTE 1 – The two domains shown in Figure 9-5 may reside in the same layer or span across different layers.

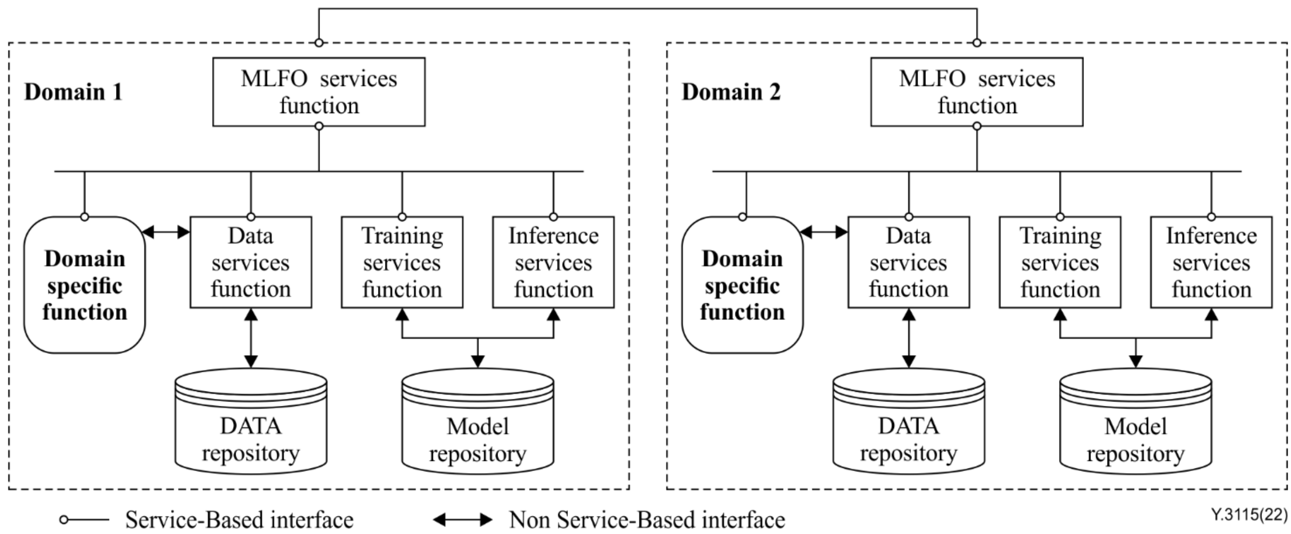

Figure 9-5 – An example of domain functionalities and interactions

There are three different types of components in a given domain: Domain specific function, AI service function (data services function, training services function, inference services function, MLFO services function) and repository (data repository, model repository).

The following details the different components used in a given domain.

– The domain specific function component provides data (related to that domain specific function) and consumes AI services.

– The data services function component provides data services (see clause 3.2). The data services function can act as data consumer which collects data from domain specific functions, and store it in the data repository after data pre-processing. When other AI services request data, the data services function acts as data provider retrieving and sharing data.

NOTE 2 – The data services build upon the data handling framework defined in [b-ITU-T Y.3174].

– The training services function component provides training services (see clause 3.2). The AI models produced by the training services function are stored in the model repository component.

NOTE 3 – The training services build upon the ML sandbox defined in [ITU-T Y.3172].

– The inference services function provides inference services (see clause 3.2). The inference services function consumes AI models stored in the model repository component.

NOTE 4 – The inference services build upon the model node defined in [ITU-T Y.3172].

– The MLFO services function component provides MLFO services (see clause 3.2). The service workflow orchestrated by the MLFO service function forms a complete AI service.

– The data epository component provides storage for domain related data.

– The model repository component provides storage for AI models [ITU-T Y.3176].

As shown in Figure 9-5, a service-based interface (SBI) [b-3GPP TS 23.501] is used for interaction among domain specific function component, data services function component, training services function component, inference services function component and MLFO services function component. A non-SBI interface is used for the other interactions.

NOTE 5 – As described above, the domain specific function component also interacts with the data services function component via a non-SBI interface.

10 Security considerations

The IMT-2020 network is subject to security and privacy measures. Sensitive information should be protected as a high priority in order to avoid leaking and unauthorized access.

The security and privacy related requirements specified in [ITU-T Y.3172] are applicable to this Recommendation. Specific security considerations are addressed in clauses 7 and 8.7.

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