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International Telecommunication Union
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Recommendation

ITU-T Y.3185 (12/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Future networks

Functional architecture for intelligent awareness of network requirements

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Recommendation ITU-T Y.3185

Functional architecture for intelligent awareness of network requirements

Summary

Recommendation ITU-T Y.3185 specifies the functional architecture of intelligent awareness of network requirements. What a network can do is meet various requirements. Thus, it is very important to make network operators or network service providers to be aware of various network requirements timely and accurately based on artificial intelligence (AI) and machine learning related technologies.

The scope of this Recommendation includes the following aspects related to intelligent awareness of network requirements, the introduction of intelligent awareness of network requirement; general functional architecture; network service data based functional architecture; crowd sourcing based functional architecture; functional architecture of requirement descriptor; functional architecture of requirement broker; functional architecture of requirement evaluator; and security consideration.

History*

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T Y.3185	2023-12-14	13	11.1002/1000/15742

Keywords

Functional architecture, intelligent awareness, network requirement.

* To access the Recommendation, type the URL https://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID.

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Functional architecture for intelligent awareness of network requirements

1 Scope

This Recommendation specifies the functional architecture for intelligent awareness of network requirements (INRA). The scope of this Recommendation includes:

a) Introduction of intelligent awareness of network requirement;

b) General functional architecture for intelligent awareness of network requirement;

c) Network service data based functional architecture for intelligent awareness of network requirement;

d) Crowd sourcing based functional architecture for intelligent awareness of network requirement;

e) Functional architecture of requirement descriptor for intelligent awareness of network requirement;

f) Functional architecture of requirement broker for intelligent awareness of network requirement;

g) Functional architecture of requirement evaluator for intelligent awareness of network requirement;

h) Security consideration.

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.2704] Recommendation ITU-T Y.2704 (2010), *Security mechanisms and procedures for NGN*.

[ITU-T Y.2770] Recommendation ITU-T Y.2770 (2012), *Requirements for deep packet inspection in next generation networks*.

[ITU-T Y.2771] Recommendation ITU-T Y.2771 (2014), *Framework for deep packet inspection*.

[ITU-T Y.2773] Recommendation ITU-T Y.2773 (2017), *Performance models and metrics for deep packet inspection*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 big data [b-ITU-T Y.3600]: A paradigm for enabling the collection, storage, management, analysis and visualization, potentially under real-time constraints, of extensive datasets with heterogeneous characteristics.

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

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 intelligent awareness of network requirement: A class of technologies or methods to realize awareness functions for the network requirements based on big data analysing and machine learning related technologies.

3.2.2 network requirement awareness: A class of technologies or methods to make the network owner, network service provider and network operator be aware of the current or future network requirements.

3.2.3 requirement broker: A network entity or a functional component that implements functions of requirement analysing, requirement synthesizing and requirement transforming, etc.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI	Artificial Intelligence
APP	Application
DFI	Deep Flow Inspection
DPI	Deep Packet Inspection
INRA	Intelligent Awareness of Network Requirement
ML	Machine Learning
NRA	Network Requirement Awareness
QoS	Quality of Service

5 Conventions

In the body of this Recommendation, the words should, may and can sometimes appear, in which case they are to interpret, respectively, as is/are recommended, is/are allowed to and is/are able to. The appearance of such phrases or keywords in an appendix or in material explicitly marked as informative are to be interpreted as having no normative intent.

6 Introduction of intelligent awareness of network requirement

With the development of network and other relative technologies, the network is playing and will continue to play a more important role in the daily life of people. Network technologies are still developing and trying to make networks (including the Internet) better. It is doubtless that one of the important tasks of the networks (including the Internet) is providing better service for network users. In other words, network requirements from network users are the focus and the biggest driving power of the network. All what the network can do is meet various user requirements.

There are so many network users and so many kinds of network users who have different network requirements. Then, at first, the critical problem is how the network can be aware of various timely requirements. Only when the network is aware of the user requirements, it can try to meet those requirements.

Traditionally, user requirements are achieved based on the service agreements between network users and network service providers. There are three main shortcomings about this kind of method.

- Service agreements are not set up based on accurate analysis. On the other hand, ordinary network users are not professional, and they are not able to describe what their real requirements are. Therefore, the service agreements cannot match the real requirements of the network users.
- Because service agreements are generated based on a few templates, service agreements only describe the general and macroscopic requirements, and some unique or microscopic requirements of the user requirements are neglected.
- Service agreements are not changed during a relatively long period, therefore, the feature for the requirements of the network users to change with time is not taken into account by the service agreements.

So, it would be beneficial and necessary for the network service provider to be aware of the user's timely requirements accurately and clearly. Only when the user requirements are grasped by the network service provider, those requirements can be really met.

Fortunately, big data and machine learning (ML) related technologies can help to enhance network requirement awareness (NRA). Through collecting user traffic/service data and traffic/service data distribution with time from the network and analysing the internal relationship of those data, user network behaviour, habit, interest and network resource utilization can be achieved. Then, based on the machine learning related methods, network user requirements can be mined.

While implementing network requirement awareness functions with big data and machine learning related technologies, network requirement awareness will be more intelligent, real-time and accurate. Network requirement awareness based on big data and machine learning related technologies is called intelligent awareness of network requirement (INRA).

To sum up, intelligent awareness of network requirement has the following features:

- Based on real-time data and historical data related to the users visiting the network.
- Using big data analysing and machine learning methods.
- Feedback based adjust-ability.
- Proposed to and confirmed by a network service provider.
- Making use of information and knowledge from other networks.
- Making use of historical knowledge about user network behaviour.

7 General functional architecture for intelligent awareness of network requirement

7.1 General architecture model for intelligent awareness of network requirement

Figure 7-1 describes a general architecture model for intelligent awareness of network requirement. This model is comprised of one or more network domains, and knowledge related to network requirements can be shared between different network domains. Within a network domain, the general architecture model for intelligent awareness of network requirement includes the following layers:

- Correlated data layer.
- Requirement source layer.
- Requirement descriptor layer.
- Requirement mining layer.
- Requirement broker layer.
- Requirement evaluator layer.

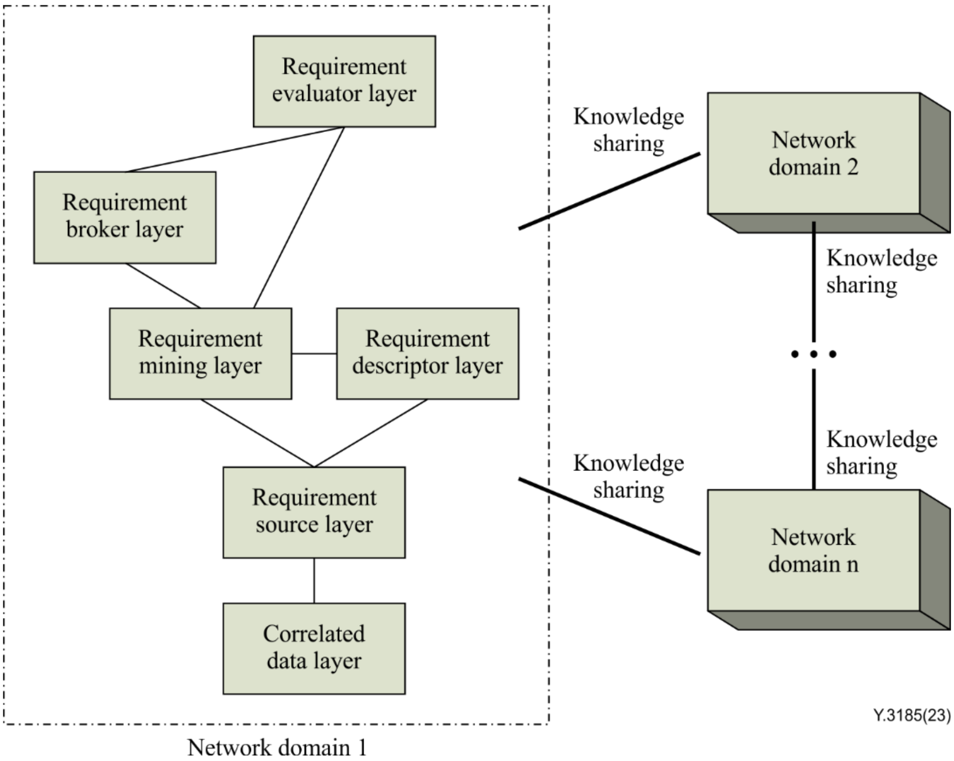

Figure 7-1 – General architecture model for intelligent awareness of network requirement

7.2 Functions for layers in the general architecture model

- Correlated data layer: it is responsible for data collecting and data correlated pre-processing for potent network requirements.
- Requirement source layer: it is responsible for acquiring potent network requirements based on the correlated data layer.

  NOTE – Potent network requirements are network requirements extracted from collected data directly and they are not surely true and reasonable network requirements.
- Requirement mining layer: it is responsible for mining true and reasonable network requirements based on the potent network requirements.
- Requirement descriptor layer: it is responsible for the representation of mined network requirements.
- Requirement broker layer: it is responsible for analysing and matching the mined network requirements with the network capability and network resources.
- Requirement evaluator layer: it is responsible for evaluating whether the mined network requirements are feasible and reasonable.

7.3 Functional component of intelligent awareness of network requirement

The general model described in Figure 7-1 implies that there are following functional components which are needed by intelligent awareness of network requirement. It is noted that all the following functional components except for network data generating entity are corresponding to the layers in Figure 7-1 respectively.

- Network data generating entity (corresponding to network itself and network users).
- Correlated data collecting entity (corresponding to correlated data layer).
- Potent requirement acquiring entity (corresponding to requirement source layer).
- Requirement intelligent analysis entity (corresponding to requirement mining layer).
- Requirement representation entity (corresponding to requirement descriptor layer).

- Requirement transforming and brokering entity (corresponding to requirement broker layer).
- Requirement evaluation entity (corresponding to requirement evaluator layer).

It is learned from clause 6 that network requirements are not achieved from network users directly, but extracted from the information collected from the network itself when INRA is used. Under such circumstances, the unique approach is making full use of the information collected from the network.

So, network data generating is the beginning of the intelligent awareness of network requirement (INRA) and this function is realized by the network data generating entity (network itself, network partition or network user etc.). The network data is various and large-scale, so correlated collection is also an important function that is implemented by correlated data collecting entities.

The potent requirement acquiring entity is responsible for achieving requirements from correlated network data directly. The most important and complicated function is achieving real and reasonable requirements from potent network requirements and other relevant data because the target of intelligent awareness of network requirement is achieving the network requirements. This function relies on requirement intelligent analysis entity.

It is necessary to represent and store the network requirements for future use and the requirement representation entity is responsible for this function. In addition, there is a need to judge whether the generated requirements are reasonable, correct and feasible or not, and the requirement evaluation entity can do the work. Before the generated requirements enter the requirement evaluation entity, transformation and resource analysis are possibly needed, and the requirement transforming and brokering entity will finish the task.

NOTE – As to the practical implementation for INRA, some of the above entities can be merged, split or omitted according to necessity of the solution.

7.4 Interface description for intelligent awareness of network requirement

There are several functional entities within a network domain and those functional entities need to collaborate to realize intelligent awareness of network requirement. So, there are several interfaces between collaborating functional entities.

NOTE – Network domain is a part of a network that is independent of the other part of the network or a network that is independent of the other network.

On the other hand, information exchange is also possible between two different network domains, then the interface between network domains is also necessary.

7.4.1 Interfaces within a network domain

There are several interfaces within a network domain, the following are those interfaces:

- Interface U_{rd}: the interface between network data generating entity and correlated data collecting entity.
- Interface U_{rp}: the interface between correlated data collecting entity and potent requirement acquiring entity.
- Interface U_{pa}: the interface between potent requirement acquiring entity and requirement intelligent analysis entity.
- Interface U_{as}: the interface between requirement intelligent analysis entity and requirement representation entity.
- Interface U_{rs}: the interface between correlated data collecting entity and requirement representation entity.
- Interface U_{ab}: the interface between requirement intelligent analysis entity and requirement transforming and brokering entity.

- Interface U_{tb}: the interface between requirement transforming and brokering entity and requirement evaluation entity.

NOTE – The above interfaces can also be thought as interfaces between layers. For example, U_{rp} can be thought as the interface between correlated data layer and the requirement source layer.

7.4.2 Interface between two different network domains

There is also an interface between two different network domains, the interface is represented by U_{DD}.

7.5 Main classes of model for intelligent awareness of network requirement

There are two representative classes of a basic model for intelligent awareness of network requirement. It is noted that implementation for INRA is not limited to the two classes of a basic model, other feasible model can also be applied to realize the function for INRA.

The following are the aforementioned two classes of models:

- Multiple-dimensional network service data based model: it focuses on the information collected from the network itself.
- Crowd sourcing based model: it focuses on the information collected from the network users.

8 Functional architecture for INRA based on multiple-dimensional network service data

8.1 Overview of INRA based on network service data

INRA based on network service data aims at mining user requirements from the user service data. The process of intelligent awareness of network requirement based on the service data can be summarized as a process illustrated in Figure 8-1. And the process includes five main procedures (other possible procedures implied in clause 7 are not illustrated in detail here) as follows:

- Multiple-dimensional network service data collecting.
- Network service data representing and transforming.
- Analysis based on multiple-dimensional network service data.
- Mining user requirements.
- Evaluating user requirements and bringing forward proposals.

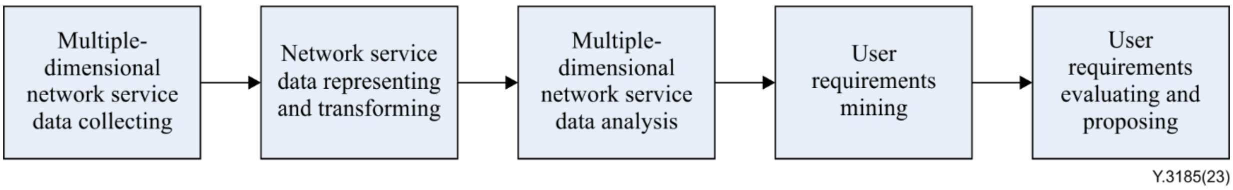

Figure 8-1 – Intelligent awareness of network requirement based on network service data

It is noted that the aforementioned five procedures are not one-to-one corresponding to layers described in Figure 7-1, but the functions in all the layers can be mapped into the five procedures. Furthermore, the aforementioned process is a cycled process, and the last iteration can be taken as an input of the next cycle.

8.2 Multiple-dimensional network service data collecting

It is necessary to collect multiple-dimensional network service data for INRA based on the service data. The aforementioned multiple-dimensional network service data includes but is not limited to the following aspects:

- User service traffic distribution with time.
- User preferred service category.
- User preferred website.
- Duration for users to visit the network.
- User terminal device performance parameter.
- User mobility attribution.
- Other features related to user network behaviour.

Various technologies and methods can be used to collect multiple-dimensional network service data. For example, deep packet inspection (DPI), (detailed information can be seen in [ITU-T Y.2770], [ITU-T Y.2771] and [ITU-T Y.2773]) and deep flow inspection (DFI) can be used to collect data such as 'user service traffic distribution with time' and 'user preferred service category'. DFI is a packet filtering technique that analyses statistical characteristics such as packet lengths, ratio of large packets and small payload standard deviation, and connection behaviour of flows, to determine the actions to be applied to application (APP) flow or session packets (e.g., classify, mark, redirect, block, drop).

8.3 Service data representing and transforming

When multiple-dimensional user service data have been collected, it is needed to be represented with a certain data structure that is appropriate for the analysis stage.

Sometimes, the collected data is difficult to be used directly by the analysis functions, then, it is necessary to transform the collected data to the formation that can be easily used by the analysis function.

8.4 Analysis for multiple-dimensional service data

Multiple-dimensional network service data is dispersed information, it is necessary to find the internal connection and relationship of those dispersed information. The functional component that realizes the analysis of multiple-dimensional network service data is responsible for finding the internal connection and the relationship.

Figure 8-2 illustrates the process analysis for multiple-dimensional network service data. The target of this process is achieving user network behaviour of the multiple-dimensional network service data.

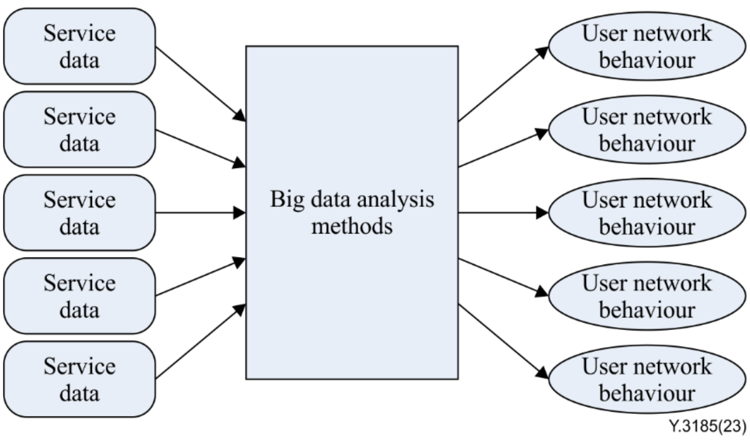

Figure 8-2 – Analysis of multiple-dimensional network service data

The function of this stage is using the collected and transformed service data, through big data analysis methods, and getting useful information for 'user network behaviour'. It is noted that 'big data analysis methods' is just a representative method, other data processing methods and technologies can also be used.

8.5 Mining network user requirement based on machine learning

The target for mining network user requirement function is achieving possible user requirements based on the attributions related to the user and the attributions about the network.

Figure 8-3 illustrates the process of mining the network user requirements. The process includes the following two stages:

- Getting user preference from the user network behaviour.
- Getting possible user requirements from the user preference and the network resource.

The first stage aims at extract user preference that is much related to the user potent requirements. Usually, network users cannot describe their requirements to the network accurately. However, their behaviours to use the network can often expose their preferences.

User preference is yet not the confirmed user requirements, and the final user requirements have a tight connection with the network resource. The second stage tries to get the confirmed user requirements based on the relevant information.

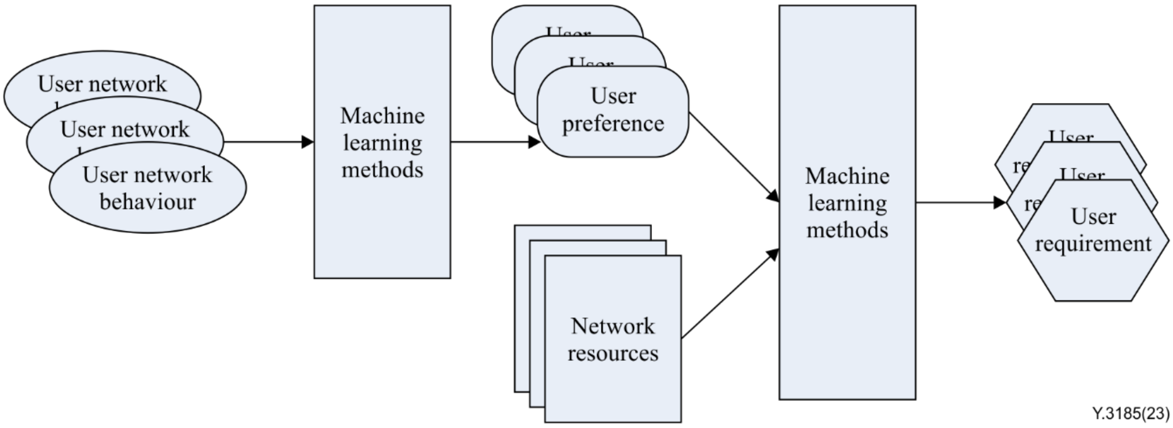

Figure 8-3 – Network user requirement mining

8.6 Network user requirement evaluating and proposing

Before realizing the user requirements generated by the network user requirement mining function, it is necessary to evaluate the feasibility and reasonability of those user requirements. This function relies on the network user requirement evaluating and proposing components.

Figure 8-4 illustrates the process for evaluating the network user requirements and bringing forward the proposals. The network in Figure 8-4 is just a virtual network generated by a network simulator, however, the simulated network has similar features of the physical network.

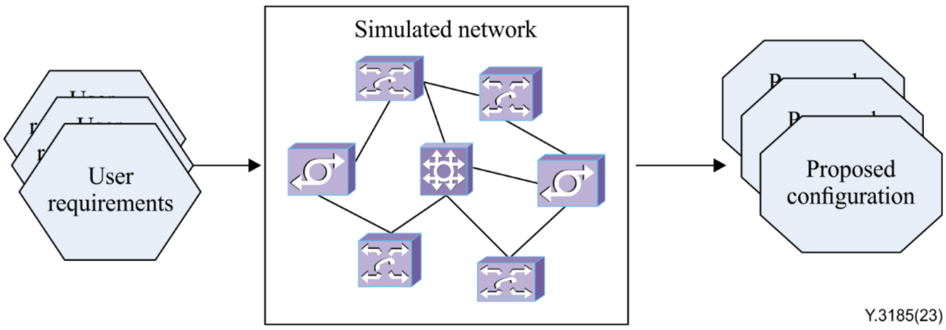

Figure 8-4 – Network user requirement evaluating

This state is based on the user requirements mined at the last stage and applies those requirements to the simulated network. When those requirements are running on the simulated network and confirm that they are feasible, then some proposals will be brought forward to configuring those user requirements to the physical network.

9 Crowd sourcing based functional architecture for INRA

9.1 Overview of crowd sourcing based INRA

Crowd sourcing is a sourcing model in which an individual or an organization can get support from a large, open-mined, and rapidly evolving group of people in the form of ideas, micro-tasks, finances, etc. Crowd sourcing typically involves the use of the Internet to attract a large group of people to divide tasks or to achieve a target. For example, traffic APPs encourage drivers to report accidents and other roadway incidents to provide real-time, updated information on APPs users.

Similar to traffic APPs, an APP that is used to collect network requirement information and network status information can be used to encourage network users to report the real-time network data related to the network users. Then through the intelligent analysis of the collected real-time network data, real-time network requirements can be achieved.

9.2 Functional architecture for crowd sourcing based INRA

Figure 9-1 can be used to describe the typical model for the functional architecture of crowd sourcing based INRA.

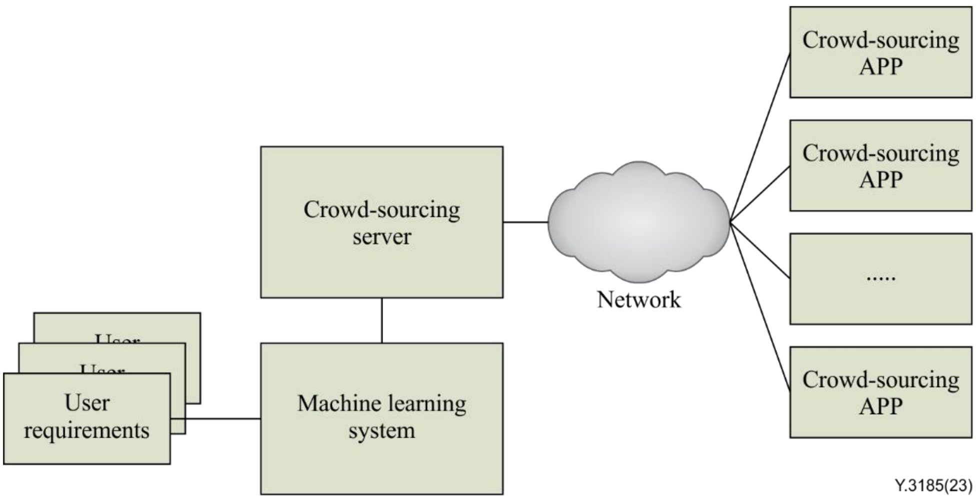

Figure 9-1 – Functional architecture for crowd sourcing based INRA

In Figure 9-1, the 'crowd sourcing APP' is the most important functional components of the aforementioned functional architecture and it is responsible for collecting the necessary information for INRA. On the other hand, the machine learning system is another basic functional component which can transform the collected data to predict the user requirements.

Based on the typical functional architecture described in Figure 9-1, there are several functions to be implemented, and the following are those functions.

- User related data collecting.
- User related data representing.
- User related data analysing based on machine learning (ML).
- User requirement generating.
- User requirement evaluating.

The above functions compose a process of crowd sourcing based INRA and Figure 9-2 can illustrate the process.

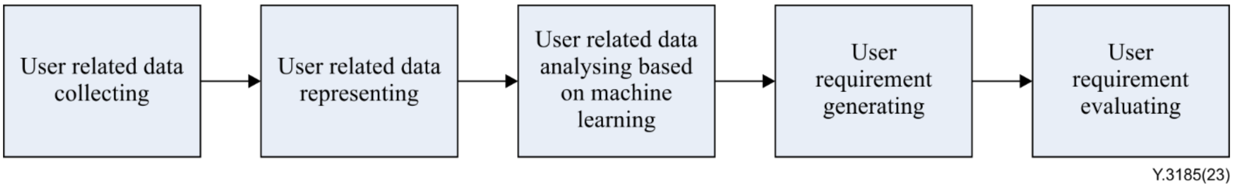

Figure 9-2 – The process for crowd sourcing INRA

9.3 User related data collecting and representing

The first two steps are correlated with each other, so they are described in this clause.

User related data collecting is the main function of crowd sourcing. However, a user data template should be introduced into the crowd sourcing APP so that the network users can report the network data related to them based on the user data template.

In addition, user related data representing the needs also depend on the user data template. One of the representing methods is representing the user related data based on the user data template directly. The other representing method is representing the user related data independent to the user data template and a transformation process between them is necessary.

9.4 Analysing user related data based on machine learning

The third step is analysing user related data based on machine learning. Its responsibility is to find knowledge related to connections between the user requirements and the user related network data.

9.5 User requirement generating

The fourth step is generating potential user requirements based on the knowledge generated in the third step. Its outputs are beneficial to network operators and network service providers because they can optimize the network based on the generated network requirements.

9.6 User requirement evaluating

The generated user requirements in the fourth step should be proven to be reasonable and feasible before they are used by network operators and network service providers. So, the step for user requirement evaluation is necessary. The responsibility for this step is to verify whether the generated user requirements are reasonable and feasible or not. Only those user requirements which are reasonable and feasible can be used by network operators and network service providers.

10 Functional architecture of the requirement descriptor layer

10.1 Requirement descriptor layer designing

Requirement descriptor layer is responsible for collecting all-direction network requirements from all the requirement sources and transforming the network requirements to the formation that all the functional components that may use the network requirements can understand the network requirement information very well.

Figure 10-1 describes the general workflow for the requirement descriptor layer. The workflow includes the following five steps:

- Requirement input.
- Requirement representation.
- Requirement storing.

- Requirement transformation.
- Requirement sharing.

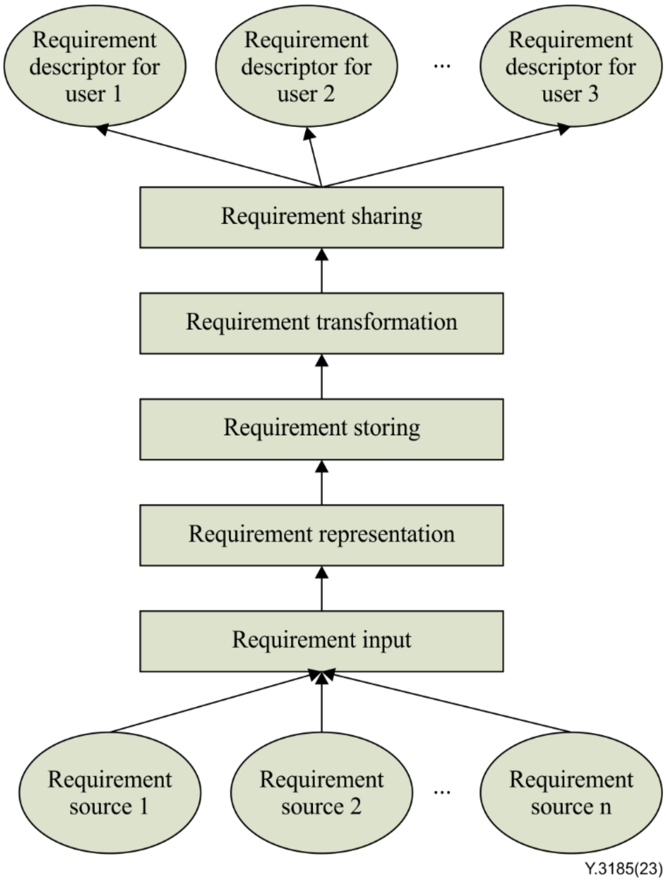

Figure 10-1 – Workflow of the requirement descriptor layer

An example of the requirement descriptor can be seen in Figure 10-2.

Requirement No.	Requirement name
Requirement source	Requirement description
Start time	End time
Item 1	Item 1 length
Item 1 parameter 1	Item 1 parameter 2
...	Item 1 parameter n
Item 2	Item 2 length
...	...

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Figure 10-2 – An example of the requirement descriptor

10.2 Requirement descriptor sharing

The requirement descriptor sharing procedure of the requirement descriptor layer is responsible for providing requirement data to the functional components that need the requirement data. It is noted that the requirement data should be provided with a proper formation so that those functional components can understand the requirement data well.

Therefore, it is needed that the requirement descriptor layer negotiates with those functional components to generate a common data structure that can be understood by both the requirement descriptor layer and those functional components.

10.3 Requirement descriptor transforming

When the data structure of the requirement descriptor in the requirement descriptor layer is different from the data structure of the requirement that is shared between the requirement descriptor layer and those functional components, the requirement descriptor transforming process is necessary before the requirement data is sent to those functional components.

It is recommended that the data structure of the user requirement and the data structure of the requirement descriptor is designed to be identical in order to save the processing cost. Under such circumstances, the requirement descriptor transforming procedure can be bypassed.

However, considering the majority of the design and deployment, it is difficult to guarantee that the data structure of the user requirement and the data structure of the requirement descriptor is identical, then the requirement descriptor transforming procedure should be used.

11 Functional architecture of the requirement broker layer

11.1 General functional architecture of the requirement broker layer

Figure 11-1 illustrates the general functional architecture of the requirement broker layer. It mainly includes information components including user requirements, network capabilities, broker rules, broker matrix and functional components including input function, broker engine and output function.

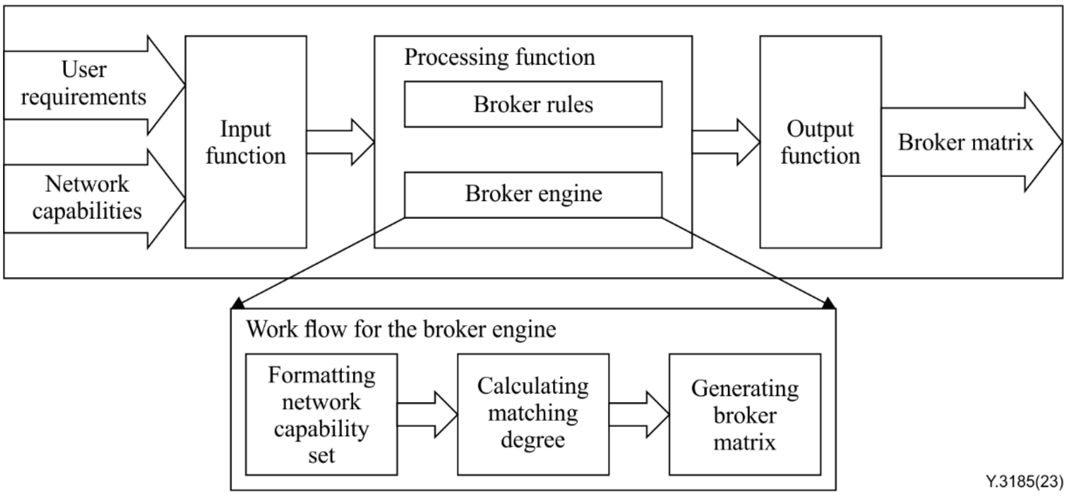

Figure 11-1 – General functional architecture of the requirement broker layer

User requirement: the requirement of the network user, it refers to the user requirement mined or generated. Through the process based on machine learning, it forms a set of user requirements. The user requirement may include a set of user requirement types and a set of weight factors.

Network capability: the ability of the network, network capability changes dynamically with the satisfaction of the user requirement. In order to match the user requirement accurately, it is necessary to provide a real-time network capability state. The dynamic network capabilities can be received by intelligent awareness methods. And the network capabilities can be represented by a set that includes multiple capability elements.

Broker rule: a kind of rule that is used by the broker engine to match the network requirement and the network capability.

Broker matrix: a reasonable mechanism in which the network capability is assigned to the user requirement. The reasonable network capability allocation matrix is generated according to the function of the requirement broker layer by user requirement set and the network capability set. For example, user requirement set with M elements, and a network capability set with N elements, after executing the function of the requirement broker layer, generates a broker matrix of M rows and N columns, and each row of the broker matrix represents a network capability vector assigned by the user requirement.

The broker rules include four kinds of relationships:

- One-to-one, one user requirement is met by one network capability;
- One-to-many, one user requirement needs multiple network capabilities;
- Many-to-one, multiple user requirements are met by one network capability;
- Many-to-many, and multiple user requirements need multiple network capabilities.

The broker rule solves the reasonable correspondence between the user requirement and the network capability.

Input function: it is responsible for collecting the necessary information for the broker engine.

Broker engine: it is responsible for generating the useful information based on the input data.

Output function: it is responsible for submitting the useful information generated by the broker engine to the functional components that need that information.

11.2 Capability of the requirement broker layer

Network capabilities can be changed, and some new capabilities type can be added meanwhile some invalid network capabilities type can be deleted in time. In other words, dynamic scalability of network capabilities can be maintained.

Network capability refers to the network functions, network resources, and some enhanced capability in transmission between the communication devices.

Network functions include addressing, routing, forwarding, quality of service (QoS) queue, congestion control and other functions, as well as the performance factors such as delay, throughput, jitter, packet loss rate, etc.

Network resources include link resources, computing and storage resources, address resources, etc.

Enhance capabilities include network security and other network capabilities, such as network security including credibility (source address authentication, authentication), privacy (encryption), reliability (integrity verification), traceability (package labelling, logging), etc.

11.3 Processing procedure of the requirement broker

Figure 11-1 also illustrates the processing procedure of the requirement broker. The procedure mainly includes the following steps:

- Formatting network capability set.
- Calculating the matching degree between the user requirement and the network capability.
- Generating the broker matrix.

1) Formatting network capability set

The process of network capability set includes analysing the user requirement, selecting single or multiple network capabilities to satisfy the user requirement, and forming a network capability set.

By traversing through the user requirement set, retain the network ability with a related relationship and delete the network ability with the mutually exclusive relationship in the network capability set. Finally, form a new network capability set.

Since different network capability types support the same user requirement, network capability set can be obtained through flexible arrangements.

2) Calculating the matching degree between the user requirement and the network capability

The matching degree is the difference in the network capability to meet the user requirement. For example, as a functional requirement, it is 1 when the obtained network capability satisfies the user requirement, and it is 0 when it is not; as a performance requirement, it is the difference between the acquired network capability metric and the user requirement.

The matching degree algorithm is to calculate the gap between the user requirement set and the acquired network capabilities set. For example, a simple matching degree algorithm is to calculate the distance between a user requirement vector and its acquired network capability vector, also the matching degree is determined by comparing the distance.

3) Generating the broker matrix

After calculating the matching degree for each user requirement, the network capability with the highest matching degree is selected to generate the broker matrix between the user requirement and the network capability.

12 Functional architecture of the requirement evaluator layer

12.1 Capability of the requirement evaluator

The task and target of the requirement evaluator are evaluating and verifying whether the network requirements achieved by the intelligent awareness are feasible (the network requirements can be supported by the network) and efficient (The utility of the network resources is economic when the network meets those network requirements).

The requirement evaluator should support the following capabilities:

- Requirement evaluator should have the capability to evaluate a network that is similar to the physical network logically. In other words, the evaluated network should have the same network transport capacity and the same network topology.
- Requirement evaluator should have the capability to dynamically change the evaluated network in order to keep it synchronized with the physical network when the physical network changes.
- Requirement evaluator should support the capability to send the collected network requirements to the evaluated network in order that the evaluated network can evaluate the network requirements.
- Requirement evaluator should support the capability to report the ratio of the supported network requirements when the collected network requirements are supported by the evaluated network.
- Requirement evaluator should support the capability to report the utility of the network resource when the collected network requirements are supported by the evaluated network.

12.2 General functional architecture of the requirement evaluator layer

Figure 12-1 illustrates the general functional architecture of the requirement evaluator, and it includes the following functional components:

- Evaluating engine.

• Simulated logical network.
• Network requirement base.
• Knowledge base.
• Interface component.

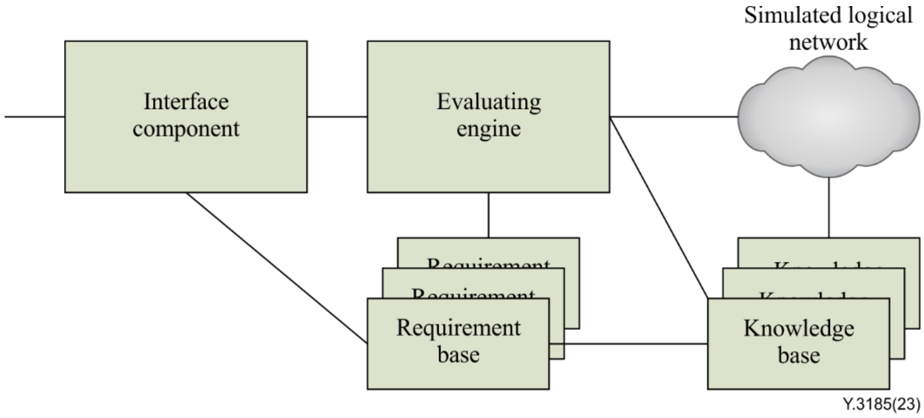

Figure 12-1 – Functional architecture of the requirement evaluator

12.3 Functional components of the requirement evaluator layer

It can be learned from Figure 12-1 that the requirement evaluator mainly includes five basic functional components. It is noted that other functional components can also be deployed in the requirement evaluator layer if they are beneficial to evaluate the achieved network requirements.

Simulated logical network is a virtual network and it can be thought of as a mirror of the physical network. Simulated logical network has the same network topology and network capability as the physical network.

Evaluating engine is the core processing component that realizes all the necessary actions to let the simulated logical network try its best to support the network requirement.

Interface component is responsible for receiving data from outside of the requirement evaluator layer and sending data from the requirement evaluator layer to the outside. The received data include the network requirements, physical network topology, physical network capability, knowledge from outside and so on. The sent data include supported network requirement set, resource utilization of the simulated logical network and so on.

Requirement base is the logical database that stores the sensed network resources.

Knowledge base is the logical database that stores the knowledge that associates the sensed network requirements with the simulated logical network.

13 Security consideration

When implementing intelligent awareness of network requirement (INRA), security best practices should be adopted such as authentication, authorization and access control as described in [ITU-T Y.2704].

In addition, operation related to the network resources should have multiple reliability guaranteeing measure in order to avoid incorrect operation to the network resources and cause degrading of the network performance.

Bibliography

[b-ITU-T Y.3600] Recommendation ITU-T Y.3600 (2015), *Big data – Cloud computing based requirements and capabilities*.

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

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