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International Telecommunication Union
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Recommendation

ITU-T Y.3160 (05/2023)

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

Future networks

Architectural framework of end-to-end service level objective guarantee for future networks including IMT-2020

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Recommendation ITU-T Y.3160

Architectural framework of end-to-end service level objective guarantee for future networks including IMT-2020

Summary

Recommendation ITU-T Y.3160 describes the architectural framework of end-to-end service level objective (SLO) guarantee for future networks including IMT-2020, which considers the following issues:

– Overview of SLO guarantee;

– A mechanism for SLO guarantee;

– The SLO design and acceptance method.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T Y.3160	2023-05-14	13	11.1002/1000/15533

Keywords

IMT-2020, network slice, service level objective, SLO guarantee.

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Architectural framework of end-to-end service level objective guarantee for future networks including IMT-2020

1 Scope

This Recommendation specifies high-level end-to-end service level objective (SLO) guarantee architecture, and the network planning impact and acceptance method for future networks including IMT-2020. This Recommendation includes:

– An overview of SLO guarantee;

– A mechanism for SLO guarantee;

– SLO design and acceptance method.

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 E.860] Recommendation ITU-T E.860 (2002), *Framework of a service level agreement*.

[ITU-T Y.3100] Recommendation ITU-T Y.3100 (2017), *Terms and definitions for IMT-2020 network.*

[ITU-T Y.3154] Recommendation ITU-T Y.3154 (2020), *Resource pooling for scalable network slice service management and orchestration in the IMT-2020 network.*

[ITU-T Y.3156] Recommendation ITU-T Y.3156 (2020), *Framework of network slicing with AI-assisted analysis in IMT-2020 networks*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 key performance indicator (KPI) [b-ITU-T Y.4051]: Indicator representing the resource usage effectiveness or efficiency of a given system.

3.1.2 network slice instance [ITU-T Y.3100]: An instance of network slice, which is created based on a network slice blueprint.

NOTE 1 – A network slice instance is composed of a set of managed run-time network functions, and physical/logical/virtual resources to run these network functions, forming a complete instantiated logical network to meet certain network characteristics required by the service instance(s).

NOTE 2 – A network slice instance may also be shared across multiple service instances provided by the network operator. A network slice instance may be composed of none, one or more sub-network slice instances which may be shared with another network slice instance.

3.1.3 service level agreement (SLA) [b-ITU-T Y.3106]: A formal agreement between two or more entities reached after a negotiating activity with the scope to assess service characteristics, responsibilities and priorities of every part. A SLA may include statements about performance, billing, service delivery but also legal and economic issues.

3.1.4 service level objective (SLO) [b-ETSI ZSM 007]: Element in a service level specification that is defined in terms of parameters, and related metrics, thresholds and tolerances associated with the parameters.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 acceptance testing: The process of evaluating the function, performance and quality of the services according to industry standards and commercial contracts at the time of services delivery.

3.2.2 service shelf: The service shelf is a series of service/product categories that are provided for customers to choose from.

NOTE – Each specific shelf service has a corresponding configurable template. Accordingly, the product can be on or off shelf, which indicates the product's status of in or not in use respectively.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AN	Access Network
BER	Bit Error Ratio
CN	Core Network
IMT-2020	International Mobile Telecommunication 2020
KQI	Key Quality Indicator
KPI	Key Performance Indicator
M&O	Management and Orchestration
NS	Network Slice
NSC	Network Slice Customer
NSI	Network Slice Instance
NSP	Network Slice Provider
PDU	Protocol Data Unit
QoE	Quality of Experience
QoS	Quality of Service
SLA	Service Level Agreement
SLO	Service Level Objective
TN	Transport Network
UE	User Equipment
UPF	User Plane Function

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.

6 Introduction of end-to-end SLO guarantee

As defined in [ITU-T E.860], the service level agreement (SLA) is a formal agreement between two or more entities reached after a negotiating activity with the scope to assess service characteristics, responsibilities and priorities of every part. A SLA may include statements about performance, tariffing and billing, service delivery and compensations. The network slice customers need to sign the SLA with network slice providers, when the network slice providers offer services, the SLA contains information about the communication service to be provided to the customer.

The information includes service specific information, i.e., service level objective (SLO) attributes and values that are needed to configure the communication service, and customer specific information, i.e., SLO attributes and values that are needed to configure the service with customer's specific information such as coverage and quality of experience (QoE) related attributes.

The SLO is the element in a service level specification that is defined in terms of parameters, and related metrics, thresholds and tolerances associated with the parameters. After receiving the SLA requirements from the network slice customers, the network slice providers can map them into SLO attributes, which can be used for configuration directly in IMT 2020 network, as shown in Figure 6-1.

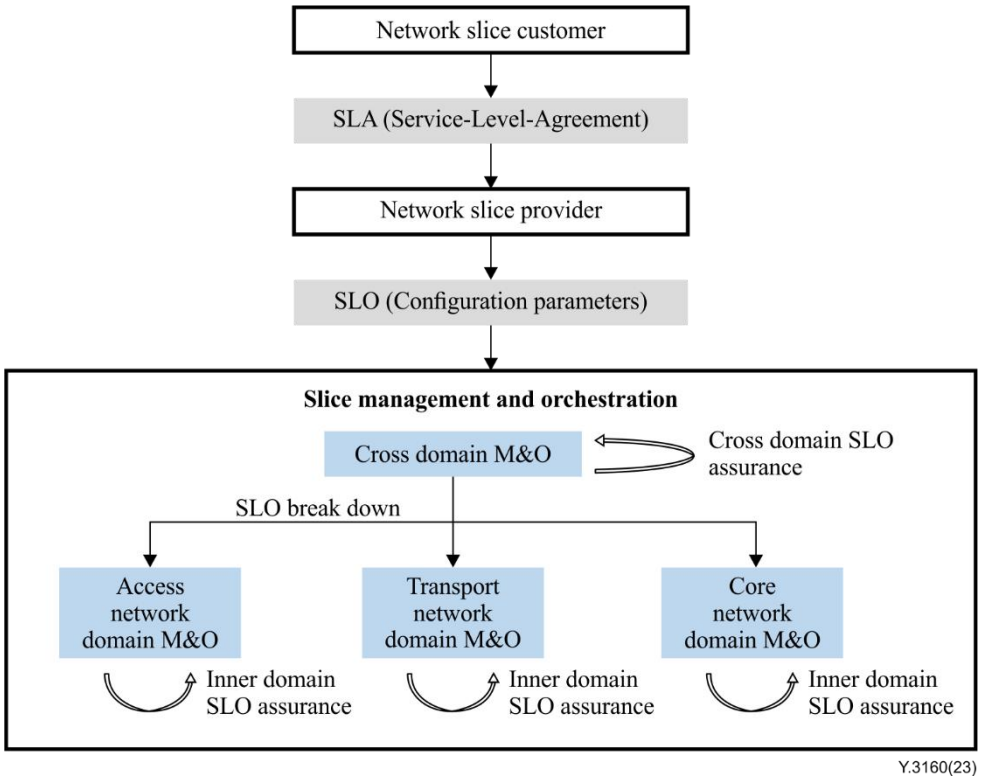

Figure 6-1 – Overview of the architectural framework of end-to-end SLO guarantee

NOTE – The scope of this Recommendation is to specify functionalities inside the system "slice management and orchestration".

For SLO guarantee, the slice management and orchestration (M&O) system needs to achieve closed loop assurance, including cross-domain SLO guarantee and sub-domain inner SLO guarantee, based on the network status and QoE feedbacks of each domain, the slice management and orchestration conducts network configuration adjustments to ensure the users' service experience.

The network slice provider (NSP) needs to take into account their customers' requirements in preparation and runtime phases of the network, which may include:

– Supporting the service requirements of the customers.

– Identifying how slice M&O could guarantee SLO with AI-assisted capabilities.

– Supporting the SLO monitoring and guarantee.

– Identifying how to design the network slicing and the acceptance method before the network deployment.

7 SLO guarantee mechanism

7.1 Requirements for end-to-end SLO break down

The slice M&O system is required to break down the SLO requirements into sub-domains, which include a set of attributes. These attributes can be performed by sub-domain M&Os (access network domain M&O, transport network domain M&O and core network domain M&O).

For supporting the access network (AN) slice SLO, attributes in the access network are recommended to contain attributes including AN slice profile ID, maximum number of user equipment (UEs), maximum number of protocol data unit (PDU) sessions, maximum bit error ratio (BER), coverage area, delay, terminal mobility level and resource sharing level.

For supporting the transport network (TN) slice SLO, attributes in the transport network are recommended to contain attributes including TN slice profile ID, guaranteed latency, guaranteed bandwidth, jitter, packet loss rate, recovery time and resource sharing level.

For supporting the core network (CN) slice SLO, attributes in core network are recommended to contain attributes including CN slice profile ID, maximum number of UEs, maximum number of PDU sessions, service area, latency, key performance indicators (KPIs) for monitoring and resource sharing level.

7.2 End-to-end SLO break down with AI-assisted analysis

The slice M&O will decompose the SLO into sub-domain SLOs， which represent the properties of the network slice related requirements that should be supported by a network slice instance. Some attributes of a SLO in sub-domain may be generated according to the related SLO requirements by the slice M&O, for example CN slice profile ID, AN slice profile ID, etc. Some attributes in a sub-domain may be inherited from the related slice M&O, for example, maximum number of UEs, maximum number of PDU sessions, guaranteed bandwidth of a network slice instance, etc. Some attributes in a sub-domain need to be broken down from slice M&O based on the properties of the sub-domain network slice instance, for example, guaranteed latency, packet loss rate, jitter, etc. When multiple network slices may be configured in the slice M&O, AI-assisted analysis and coordination of the allocation of the network slice resources is required.

AI-assisted analysis as defined in [ITU-T Y.3156] can be introduced to enable the SLO guarantee of the slice M&O.

The cross-domain M&O collects historical data from the sub-domain M&O, and the AI-assisted analysis can use AI/ML algorithms to analyse the relationship between the deployment information (e.g., service type, template information, resource characteristics, configuration parameters) and the SLO measurement data of sub-slice instances of access network, transport network and core network

(e.g., delay, bandwidth, bit rate, number of UEs), so the expected SLO requirements can match the corresponding deployment information. The cross-domain M&O decides the optimal SLO mapping based on the AI-assisted analysis, and allocates the corresponding configuration result to the sub-domain M&O.

7.3 SLO monitoring and guarantee

End-to-end network slice SLO monitoring is to support monitoring of the running status, security, faults and performance of the network slice, so as to provide network slice operation and maintenance, and network slice SLO predictions and guarantee control.

Network slice SLO monitoring and guarantee includes the following aspects:

a) SLO monitoring and guarantee:

The network slice SLO monitoring includes:

– Monitoring of sub-domain performance attributes requirements specified in clause 7.1 and over-threshold setting of sub-domain performance;

– Monitoring of end-to-end performance attributes (e.g., end-to-end delay) which are calculated after receiving the measurement results of each sub-domain M&O, and over-threshold setting of end-to-end performance to generate real-time warning;

– Monitoring of warning and fault information of the sub-domain and end to end network slice;

– Monitoring of security by detecting attacks and risks.

b) SLO prediction and guarantee:

The network slice SLO prediction includes:

– Prediction of sub-domain performance attributes requirements specified in clause 7.1 and over-threshold setting of future sub-domain performance values;

– Prediction of end-to-end performance attributes, and over-threshold setting of future end to end performance to generate pre-warning;

– Prediction of fault information of the sub-domain and end to end network slice to trigger a failback or repair;

– Prediction of attack and risk behaviour to guarantee network security.

8 SLO oriented network slicing design and acceptance

8.1 SLO oriented NS life cycle

SLO oriented network slice (NS) lifecycle management should be considered for IMT-2020 network. SLO acts on all phases of NS lifecycle procedures for the service level guarantee of an NS.

A network slice instance (NSI) as defined in [ITU-T Y.3100], can be provided by network slice provider. [ITU-T Y.3154] introduces the lifecycle management of the NSI as shown in Figure 8-1. The lifecycle of the NSI conducts two process phases:

i) preparation phase; and

ii) runtime management phase.

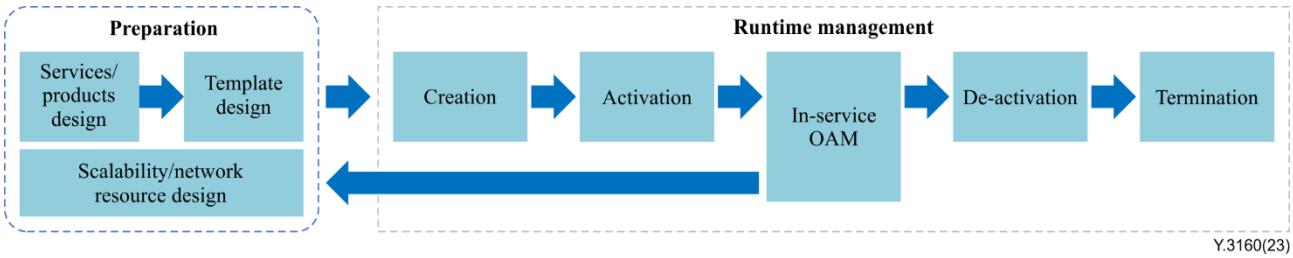

Figure 8-1 – Network slicing lifecycle procedure [ITU-T Y.3154]

In the preparation phase, it is necessary to give feedback from the runtime management phase for achieving SLO guarantee.

The preparation phase of network slicing is expected to include:

– Services/products design: It may include design of service functions, service key performance indicators (KPIs) and their monitoring, control and management methods and billing abilities with consideration of the network slice providers' business predictions and cost trade-offs. The services/products design can used to design a network slice, which can be selected in the service shelf by customers.

– Scalability/network resources design: It contributes to NS related network resource preparation. Scalability of the NS is relevant to the number of terminals, location and area, etc. The NS may be designed in accordance with different isolation requirements and resource occupancy.

– Template design: An NSP may provide a range of parameter values and a suggestion for a typical service by using pre-configurable templates to meet SLOs.

In the preparation phase, the NSI will be designed based on the procedures of services/products design, template design and scalability/network resources design.

In the runtime management phase, the NSP can provide the NSI to the NSC, and the NSI will go through the lifecycle of creation, activation, in-service operation and monitoring, de-activation and termination.

8.2 SLO oriented NS design procedure

8.2.1 Key SLOs

In the preparation phase, the NSP should prepare network resources based on SLO requirements. Figure 8-2 shows the composition of key SLOs.

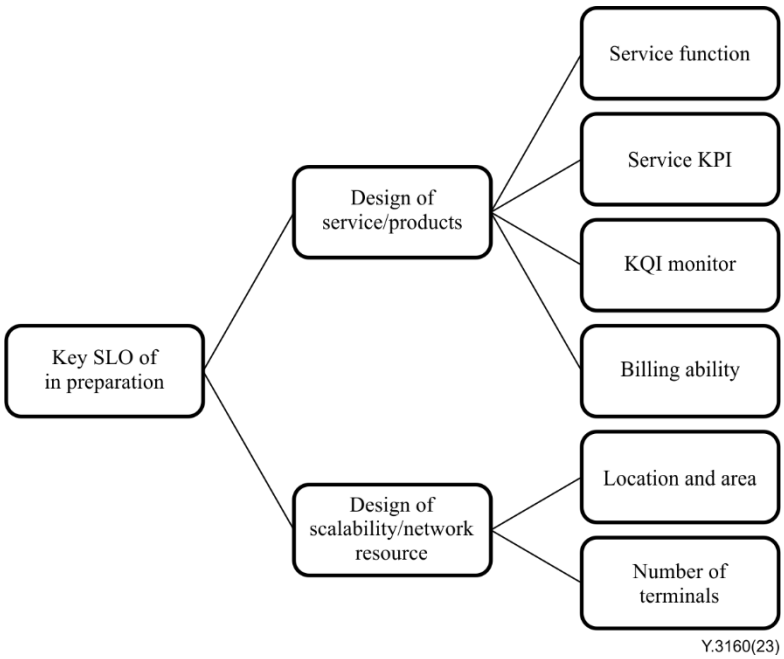

Figure 8-2 – Key SLOs in NS design

– Design of service/products refers to service/products requirements including functions, KPIs, key quality indicators (KQIs), monitoring and billing ability, etc.

– Design of scalability/network resources refers to the resource requirements of network location and the size, etc.

In the runtime management phase, each NS service provided by an NSP will occupy specific network resource coordinated with services/products and the scalability in order to provide NS services to guarantee the SLO requirements. When the available resources cannot meet the assignment of the current NS design, the NSP should prepare more resources and optimize the resource allocation.

8.2.2 Typical NS templates

A series of service/product categories is composed of service shelves for NSCs to choose from. Each specific service/product should be related to some typical NS templates with different SLO attributes such as network type, customized resources and the attributes related to the service experience of NSCs.

8.2.3 Monitor and evaluate the network resources

In the process of run time management, the NSP should evaluate the usage of resources. This clause describes the process of monitoring and evaluating the network resources.

For closed loop optimization, during the run time management phase, the result of monitoring and evaluation of the network resources should be feedback to the preparation phase, including service/products design and the scalability and resource design. If the resources cannot satisfy the SLO requirements, the NSI deployment will be refused or delayed until the resources are available.

8.2.4 NS resources adaptive adjustment for conflict prevention

Due to a burst in service demand of network slice customers, two or more network slices may request the same shared resources at a certain time. In order to ensure SLO of the network slices of high-priority services, slice resources need to be dynamically adjusted to prevent conflicts with network slices of low-priority services. The adaptive adjustment procedure is shown in Figure 8-3

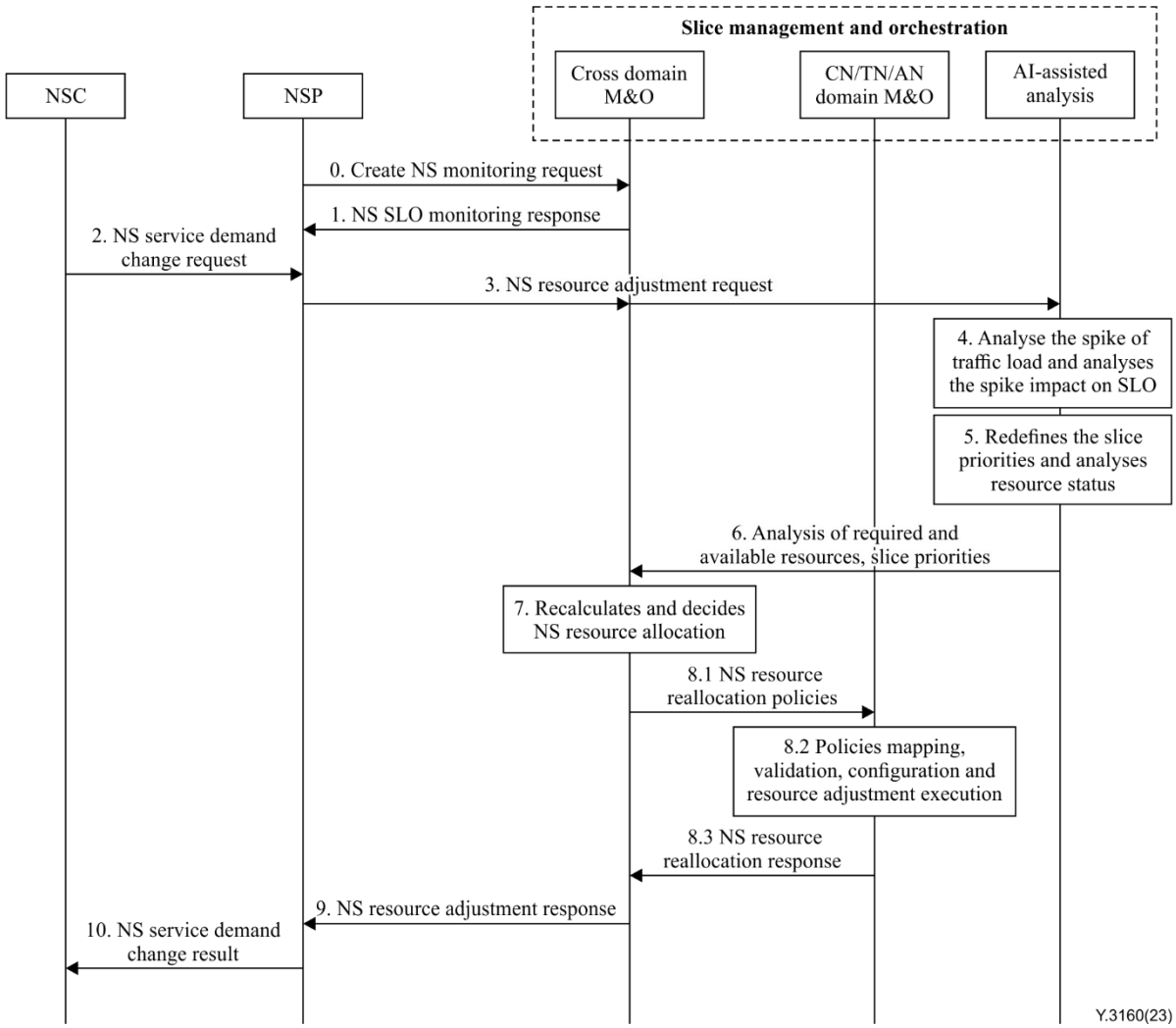

Figure 8-3 – Procedures of NS resources adaptive adjustment

Network slice providers (NSPs) can prevent NS resource conflicts by the following actions:

0) NSP requests slice management and orchestration to create NS monitoring once the network slice (NS) service is created for NSC.

1) NSP continuously receives NS SLO monitoring results and evaluates NS resource usage through the monitoring procedure described in clause 7.3.

2) NSP receives a service change request from NSC (e.g., emergency live video, etc.) which will cause a sudden increase of resource demand and may cause network slices resource conflicts.

3) NSP sends the NS resource adjustment request to the cross-domain M&O, and the cross-domain M&O forwards an analysis request of resources to the AI-assisted analysis function defined in [ITU-T Y.3156].

4) The AI-assisted analysis function detects and predicts the spike of traffic load in a specific zone, initiates NS resource adaptive adjustment analysis, and analyses if the spike will impact on the service delivery on whatever strict SLO is agreed.

5) The AI-assisted analysis function redefines the slice priorities based on NSC's requirements of each network slice and the agreed SLO to avoid the conflict, and analyses required and available resources for each network slice.

6) The AI-assisted analysis function sends the analysis results of network slice resources and priorities to the cross-domain management and orchestration function.

7) The cross-domain management and orchestration function recalculates and decides NS resource allocation based on priority and analysis results, for NSs with higher priority, the policy will be scaling up/out resources, and for NSs with lower priority, the policy may be traffic control, admission control, etc.

8.1) The cross-domain management and orchestration function sends the NS resource reallocation policies to the single domain (e.g., AN/TN/CN) management and orchestration function.

8.2) The sub-domain management and orchestration function adjusts resources after mapping, validation and configuration based on the NS resource reallocation policies.

8.3) The sub-domain management and orchestration function responds the results of NS resource reallocation to the cross-domain M&O.

9) The slice management and orchestration function sends the NS resource adjustment response to NSP.

10) The NSP sends the notification of conflict prevention of the NS service demand change to the NSC.

8.3 SLO oriented network acceptance process

8.3.1 SLO oriented acceptance requirements

Acceptance is a process conducted to determine if the requirements of a specification or contract are met. SLO oriented acceptance refers to the evaluate and guarantee process to determine if the NS capabilities delivered to customers in vertical industries meet the requirements of SLOs. The process shall be provided at the time of network delivery and during its runtime. Unlike individual users, the requirements of vertical industry customers are characterized by complex scenarios, diverse requirements and significant customization. Even different customers in the same industry may have different network functions and performance requirements. For instance, the rate should be a key attribute of the NS capability in the ultra HD video-on-demand scenarios. Ultra-low latency and ultra-high reliability should be the key attributes in V2X requirements. Low power consumption and coverage should be the key attributes in the massive IoT scenarios. SLO oriented network acceptance is therefore required.

8.3.2 SLO oriented acceptance process in NS lifecycle

After the preparation phase shown in Figure 8-1, the NS lifecycle procedure enters the runtime management phase in which the creation stage is expected to consist of two processes which are the building process and the acceptance process, as shown in Figure 8-4. The building process creates a NSI in which all resources to the NSI have been created and pre-configured to satisfy the network slice requirements. Acceptance process executes the final verification. The acceptance process includes acceptance testing, network commissioning and complete commissioning. The NS lifecycle procedure enters the activation stage after the stage of complete commissioning.

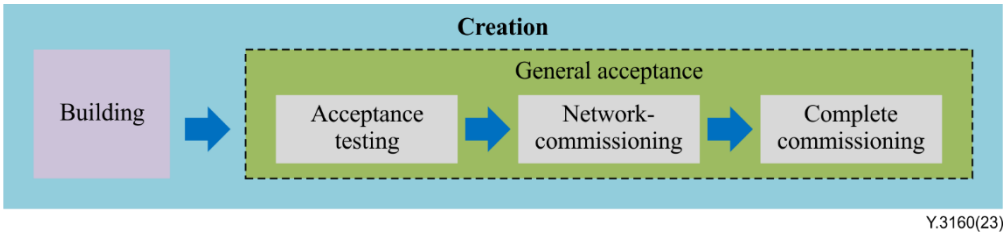

Figure 8- 4 – Composition of creation stage in NS lifecycle

– Acceptance testing: Successful completion of acceptance testing means the tested NS capabilities can meet customers' SLO requirements.

– Network commissioning: In this step, a NSI is created and can be used for services. A set of key network attributes should be monitored in this step.
– Complete commissioning: When the monitored attributes can meet the SLO requirements and the network commissioning period is finished, the network slices can be delivered to the customers.

9 Security considerations

The architectural framework of end-to-end service level objective assurance of IMT-2020 network includes AN, TN and CN that are subject to security and privacy measures. Security and privacy concerns should be aligned with the requirements specified in [ITU-T E.860], [b-ITU-T Y.3106] and [b-ITU-T Y.4051].

Bibliography

[b-ITU-T Y.3106] Recommendation ITU-T Y.3106 (2019), *Quality of service functional requirements for the IMT-2020 network.*

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