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Future networks

Framework for the support of network slicing in the IMT-2020 network

Recommendation ITU-T Y.3112

ITU-T

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Recommendation ITU-T Y.3112

Framework for the support of network slicing in the IMT-2020 network

Summary

Recommendation ITU-T Y.3112 describes the concept of network slicing and use cases of when a single user equipment (UE) simultaneously attaches to multiple network slices in the IMT-2020 network.

The use cases introduce the slice service type to indicate a specific network slice and the slice user group for precisely representing the network slice in terms of performance aspects and business aspects.

This Recommendation also specifies high-level requirements and framework for the support of network slicing in the IMT-2020 network.

History

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Framework for the support of network slicing in the IMT-2020 network

1 Scope

This Recommendation describes the concept of network slicing and use cases of when a single UE simultaneously attaches to multiple network slices in the IMT-2020 network.

The Recommendation specifies high-level requirements from the perspective of the service and the network, and provides a high-level framework in terms of network functions. Furthermore, this Recommendation introduces a slice service type and a slice user group for precisely indicating and representing a specific network slice in terms of performance aspects and business aspects.

This revision of the Recommendation provides more explanation about network slice selection, and slightly modifies the structure of the text.

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

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

[ITU-T Y.3102] Recommendation ITU-T Y.3102 (2018), *Framework of the IMT-2020 network*.

[ITU-T Y.3111] Recommendation ITU-T Y.3111 (2017), *IMT-2020 network management and orchestration framework*.

[ITU-T Y.3150] Recommendation ITU-T Y.3150 (2018), *High level technical characteristics of network softwarization for IMT-2020.*

[ITU-R M.2083] Recommendation ITU-R M.2083-0 (2015), *Framework and overall objectives of the future development of IMT for 2020 and beyond.*

[ITU-R M.2410] Report ITU-R M.2410-0 (2017), *Minimum requirements related to technical performance for IMT-2020 radio interface(s).*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 IMT-2020 [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.

3.1.2 network function [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.

3.1.3 network slice [ITU-T Y.3100]: A logical network that provides specific network capabilities and network characteristics.

NOTE 1 – Network slices enable the creation of customized networks to provide flexible solutions for different market scenarios which have diverse requirements, with respect to functionalities, performance and resource allocation.

NOTE 2 – A network slice may have the ability to expose its capabilities.

NOTE 3 – The behaviour of a network slice is realized via network slice instance(s).

3.1.4 network slice blueprint [ITU-T Y.3100]: A complete description of the structure, configuration and work flows on how to create and control a network slice instance during its life cycle.

NOTE – A network slice template can be used synonymously with a network slice blueprint.

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

3.2 Terms defined in this Recommendation

This Recommendation does not define any terms.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

3G Third Generation

4G Fourth Generation

AR Augmented Reality

eMBB enhanced Mobile Broadband

E2E End-to-End

HD High Definition

IMT International Mobile Telecommunications

KPI Key Performance Indicator

mMTC massive Machine Type Communications

MANO Management and Orchestration

MVNO Mobile Virtual Network Operator

NACF	Network Access Control Function
NF	Network Function
NS	Network Slice
NSI	Network Slice Instance
NSSF	Network Slice Selection Function
NSTI	Network Slice Type Indicator
SMF	Session Management Function
SST	Slice Service Type
SUG	Slice User Group
UE	User Equipment
UHD	Ultra-High Definition
URLLC	Ultra-Reliable Low Latency Communications
V2X	Vehicle to Everything
VR	Virtual Reality

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 and/or service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with this Recommendation.

6 Overview

The IMT-2020 network is expected to be able to support a variety of services and applications beyond the current IMT [ITU-R M.2083]. In the IMT-2020 network, the services and the applications can have a variety of different requirements on functionality (e.g., priority, charging, policy control, security, and mobility), differences in performance requirements (e.g., latency, mobility, availability, reliability and data rates), or differences in serving users (e.g., public safety users, corporate customers, roamers, or hosted MVNO) [b-3GPP TS 22.261]. Network slicing is recognized as a key enabler for the support of different types of services as it can provide services over corresponding logically isolated network slices by slicing a single physical network into multiple, end-to-end (E2E) networks [ITU-T Y.3101] [b-NGMN].

Furthermore, a broad variety of capabilities can be tightly coupled with these intended different usage scenarios for IMT-2020 [ITU-R M.2083] [b-3GPP TS 22.261]. The usage scenarios for IMT-2020 include:

– Enhanced mobile broadband (eMBB): This usage scenario pertains to high data rates, high user density, high user mobility, highly variable data rates, deployment and coverage. The enhanced mobile broadband will come with new application areas and requirements in addition to existing mobile broadband applications for improved performance and an increasingly seamless user experience.

– Massive machine type communications (mMTC): This usage scenario is characterized by a very large number of connected devices typically transmitting a relatively low volume of non-delay-sensitive data. Devices are required to be low cost, and to have a very long battery life.

– Ultra-reliable and low latency communications (URLLC): This usage scenario has stringent requirements for capabilities such as throughput, latency and reliability. Some examples include wireless control of industrial manufacturing or production processes, remote medical surgery, distribution automation in a smart grid, transportation safety, etc.

Network slicing enables an IMT-2020 network operator to provide customized networks by slicing a network into multiple virtual, and end-to-end networks, referred to as network slices. Each network slice can be defined according to different requirements on functionality, performance and specific users.

Figure 6-1 illustrates the concept of network slicing. A network slice is composed of a collection of the necessary network functions (e.g., virtualized and/or physical, shared or slice specific [ITU-T Y.3101])) that support the service requirements of particular usage scenario(s). It is required to be possible to associate devices to their proper slices in order to meet the respective requirements, based on device or service type. For example, a mobile phone requesting high definition (HD) streaming service is associated to an eMBB slice. While the mMTC slice and the URLLC slice are respectively allocated to a sensor measuring the temperature for an agricultural application and an automobile using V2X communication service.

Network slicing allows the IMT-2020 network operator to provide dedicated logical networks (i.e., network slices) with customer specific functionalities. A network slice, spanning all the network segments including radio access network, transport network and core network, can be dedicated to specific types of service [ITU-T Y.3101]. When a UE is only associated to a single dedicated network slice, the IMT-2020 network can identify the association of the UE with the network slice based on user subscription, context, service provider's policy, etc. Otherwise, if a UE accesses multiple network slice instances simultaneously, it is recommended that the UE provide information to the network to assist the network slice selection process.

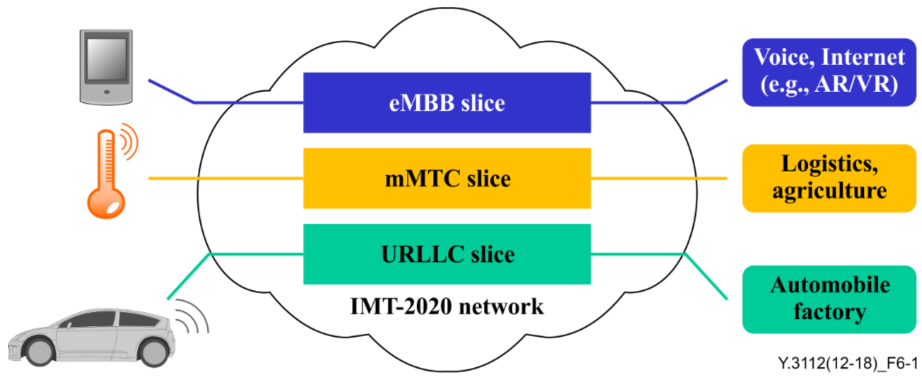

Figure 6-1 – The concept of network slicing

For each network slice, dedicated resources (e.g., virtualized network functions, network bandwidth, QoS) are allocated and an error or fault that occurs in one slice does not cause any effect in other slices.

So far, mobile networks (e.g., 3G, 4G), mainly serving mobile phones, have been optimized for voice and Internet services in a centralized deployment. However, in the IMT-2020 network, they have to serve a variety of devices with different requirements and different needs. The above-mentioned usage scenarios require different requirements on performance [b-Netmanias]. For instance, the mMTC usage scenario that connects stationary sensors measuring temperature, humidity, precipitation, etc. to mobile networks does not require features like handover or location update, which have been critical in serving mobile phones. For the eMBB usage scenario, high data rates are driven by the increasing use of data for services such as streaming (e.g., 4K/8K UHD) and interactive services (e.g., augmented reality (AR)). These services come with stringent requirements for user experienced data rates as well as associated latency requirements to meet service requirements [ITU-R M.2410]. On the other hand, the URLLC usage scenario (e.g., autonomous driving, remote controlled robots) requires, unlike mobile broadband services, a substantially lower latency as well as higher reliability. Table 6-1 provides examples of services and expected performance requirements corresponding to each usage scenario.

Table 6-1 – Examples of services corresponding to each usage scenario

Usage scenario	Typical characteristics	Examples of services
eMBB	High bit rate (e.g., 20 Gbit/s downlink peak data rate)	4K/8K UHD, hologram, AR/VR
mMTC	Massive connections	Sensor–network services(metering, agriculture, building, logistics, city, home, etc,)
URLLC	Low latency (e.g., 1 ms), high reliability, high positioning accuracy	Motion control, autonomous driving, automated factory, smart-grid service, AR/VR
NOTE – These requirements are not intended to restrict the full range of capabilities or performance.		

Based on the concept of network slicing, some use cases for multiple network slicing are described in clause 7. Clause 8 specifies how to indicate a specific network slice and select the indicated network slice. Clause 9 and clause 10 respectively provide the high-level requirements and the framework.

7 Framework of network slicing

7.1 Functional aspects of network slicing

When a UE accesses multiple slice instances simultaneously, it should provide the IMT-2020 network with the information to assist the network slice selection process. If a UE is only associated with a single dedicated network slice, the IMT-2020 network can identify the network slice of the UE based on user subscription, context, service provider's policy, etc.

From the network slicing perspective, the network functions can be further divided into two types: UE level functions and service level functions. The UE level functions are functions that support user access to the IMT-2020 network. Network access control function (NACF) is a UE level function and it should be available in every registration area (RA). The NACF is responsible for providing registration management and mobility management [ITU-T Y.3102]. An instance of NACF, which has the proper capabilities to support registration and mobility management of every service session by a UE, should be selected. With the proper NACF instance selection, NACF instance relocation may happen rarely. In addition, the NACF instance logically resides in multiple network slice instances serving the UE, and interacts with other network function instances in the network slice instances.

On the other hand, other network functions such as the session management function (SMF) belong to the service level functions. They can exist within different network slice instances providing the relevant KPIs. The SMF is responsible for providing session management and data path control in the IMT-2020 networks [ITU-T Y.3102]. When the UE requests a single service session with a specific capability, a proper instance of SMF should be selected supporting such capability.

From the UE perspective, a number of different service sessions can be initiated at the same time, and each service session should be served by the appropriate network slice instances. In addition, each network slice instance should include the specific network function instances that satisfy the related service requirements. Therefore, the NACF instance should be selected to be able to meet the highest demand of performance requirements among the multiple NACF instances. On the other hand, the SMF instance should be selected in each corresponding network slice instance.

From the network perspective, different network slices should be enough isolated from each other in order to minimize their interference. This means that communications between different service level network functions (e.g., SMF) within a network slice can be possible. In addition, as the network slice instance is the realization of a network slice, which is created based on network slice blueprint [ITU-T Y.3100], multiple network slice instances can be instantiated according to a corresponding usage scenario (e.g., eMBB).

On the other hand, communications between an NACF instance and an SMF instance should be possible under the condition that a network slice instance is differently isolated.

Therefore, the service sessions from the UE side can be established through the single UE level network function and the multiple service level network functions in the IMT-2020 network as shown in Figure 7-1

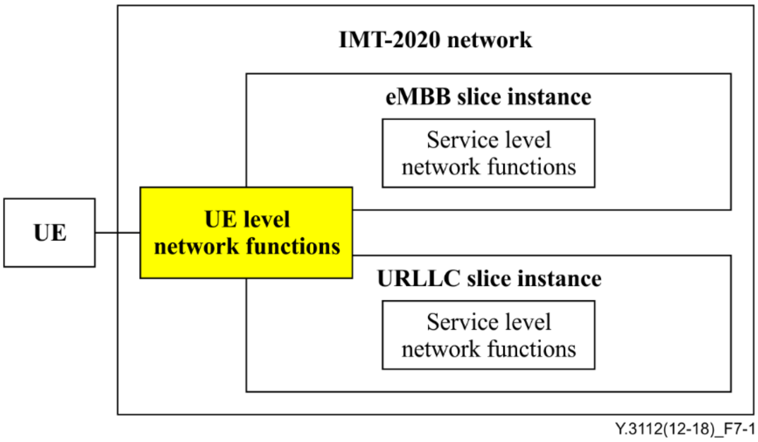

Figure 7-1 – Network functions from the UE perspective

From the network deployment perspective, network functions can be classified into two types based on whether they are sensitive to key performance indicators (KPIs) or not. A KPI-sensitive network function can be located close to the user but other types of network functions do not depend on UE location in the IMT-2020 network.

The KPI-insensitive network functions such as the network slice selection function (NSSF) and the user data management function, would be deployed in a centralized manner so that they can provide their capability support to the other network functions in the IMT-2020 network.

On the other hand, KPI-sensitive network functions may be deployed in a distributed manner. Therefore, KPI-sensitive network functions such as mobility management, session management and data path control, can be deployed close to a UE (e.g., specific area such as a set of tracking areas (TAs) and registration area (RA) in the IMT-2020 networks.

NOTE – A tracking area is a logical grouping of cells in an IMT-2020 network, and a registration area is the set of tracking areas. A registration area is an area in which the UE may roam without a need to perform location registration.

7.2 Use cases of network slicing

In general, a UE can access one network slice instance or multiple network slice instances simultaneously depending on the requesting service types and performance requirements.

As an example, this clause illustrates the use case of an autonomous driving car where a UE simultaneously accesses different network slice instances.

An autonomous driving car attaches to the network via the V2X communication service. A user, sitting in the car, initiates an HD video streaming service through the infotainment system available in the car. In this use case, the V2X communication service requires low latency but not necessarily high bit rate, whereas the HD video streaming service requires high bit rate but is tolerant to latency.

Therefore, the V2X communication service and the HD video streaming service are attached to different network slice instances satisfying their corresponding performance requirements; for example, a URLLC slice and an eMBB slice, respectively, as shown in figure 7-2.

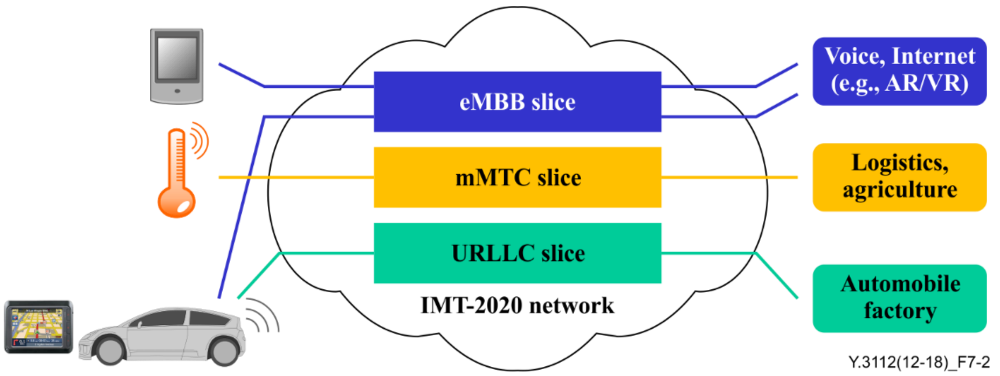

Figure 7-2 – Use case for network slicing – Autonomous driving car

From the business deployment perspective, a network slice may indicate the vehicles designed with a specific motor, and it can be used to efficiently manage and update configuration changes if the vehicles are of the same brand. Figure 7-3 shows a use case of network slice for autonomous driving cars using different motors.

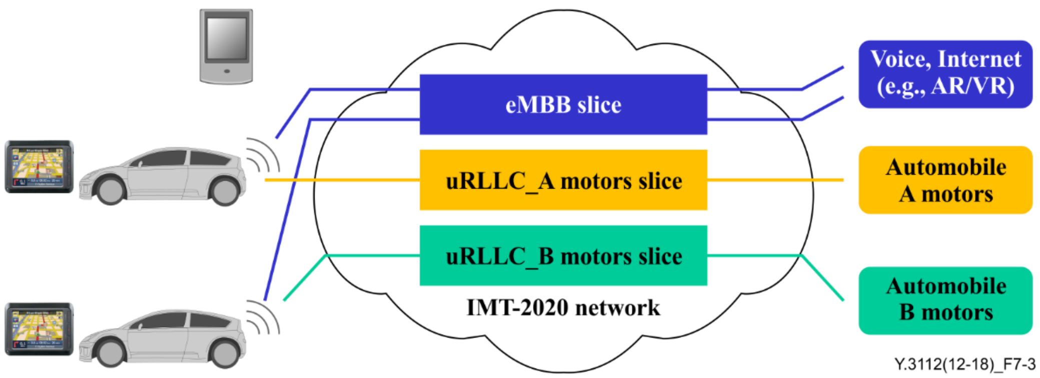

Figure 7-3 – Use case for network slicing – Autonomous driving cars using different motors

According to [b-3GPP TS 22.261], the IMT-2020 network is assumed to support motion-to-photon latency in the range of 7 ms -15 ms while maintaining the required user data rate of 250 Mb/s for virtual reality (VR). A particular service like VR likely requires both high data rate and low latency, and both eMBB and URLLC usage scenarios [ITU-R M.2083] would be associated for this. It means that the UE is recommended to provide an appropriate network slice indication information to the network in order to access the network slice that the UE needs.

7.3 Network slice indication and selection

This clause specifies how to indicate network slice and select network slice.

7.3.1 Indication of network slice

In the IMT-2020 network, network slices can explicitly be associated to the kinds of service and user groups. For example, the type of network slices may be identified in terms of different requirements of functionality (e.g., charging, policy control, security and mobility), of differences in performance (e.g., latency, mobility and data rates) and specific users (e.g., corporate customers, roamers, or hosted MVNO) [ITU-T Y.3101], [b-3GPP TS 22.261]. The type of a network slice needs to be identified with a particular indicator called a network slice type indicator (NSTI).

From the above usage scenarios, the NSTI can be defined taking into consideration three aspects: 1) key functionality, 2) performance and 3) users.

The NSTI can be comprised of two kinds of information.

– SST (Slice Service Type): represents the kinds of different services that require different key functionality and different performance of network functions. Basic SSTs are eMBB, URLLC and mMTC. Additional SSTs can be defined according to the need of finer segmentation of the performance requirements and/or operator's policy (e.g., eMBB+URLLC).
– SUG (Slice User Group): optional information that complements the SST and enables further differentiation of user groups (e.g. the user group with detailed performance requirements, the user group in a particular area).

The NSTI information is required to include all slice service types that a UE is willing to request to the IMT-2020 network when the UE is initially registered or re-registered. When receiving the NSTI information from the UE, the network verifies the NSTI information to see whether the corresponding network slice is available, based on the operator's policy and the IMT-2020 network status. The UE can provide a single NSTI when requesting a particular service session establishment to the IMT-2020 network.

7.3.2 Selection of network slice

An NSTI is required to include one SST when a UE requests a specific service to the IMT-2020 network. The SST may indicate either a usage scenario (e.g., eMBB, mMTC and URLLC) or their combination (e.g., eMBB+URLLC, etc.). Furthermore, the NSTI can optionally include an SSG as well as the SST to precisely indicate a specific network slice, where the SUG can include detailed performance requirements of different user groups in a particular area. Examples are "URLLC with a latency of 100 ms", "URLLC with a latency of 5 ms", "eMBB with 100 Mbps for users in a urban area", and "eMBB with 10 Mbps for users in a rural area".

The network determines and selects a network slice instance (NSI) based on the NSTI provided by the UE, the availability of NSI in the IMT-2020 network, operator's policy and subscription information. The NSTI can be defined more based on the operator's policy, and configured/provided to the UE. If the NSTI from UE can be applicable to the network-provided NSIs or the network-provided NSIs are a superset of the NSTI from UE, the network can select one of the NSIs to serve the UE. Otherwise, the network can reject the UE's request.

The NSI can be instantiated in a static or a dynamic way depending on whether the NSI is created at configuration time or at run time.

An NSI comprises the relevant network functions (NFs) required for providing a certain service. An NSI can also include multiple NF instances with the same features. Among the multiple NF instances, one of them can be selected considering load balancing.

In static network slicing, the NSIs are instantiated and provisioned at configuration time, and the NSI already includes the proper network function (NF). Therefore, in static network slicing, the NACF instance first chooses a proper NSI among the available NSIs and then selects the necessary SMF instance in the mobile core network. It is not allowed to pick up the NF instances within the other NSIs. The NACF instance can get the related NSI information from the NSSF.

In dynamic network slicing, the NACF instance first initiates the selection process of the proper NF instances through coordinated activities with other functions in the IMT-2020 network, and then creates an NSI comprising the NF instances according to a network slice template, in run time.

NOTE – One of the possible dynamic methods is that the NACF is assisted by a NSSF in the creation of the NSI, where the NSSF is associated with management and orchestration (MANO) [ITU-T Y.3111].

NF instances can also be added dynamically to an existing NSI if the system allows it (for example, for the purpose of saving resources when an existing slice is not operating at full load at the moment of the request from the UE). A subsequent request, from a different UE requesting the same services, will not trigger the instantiation of the needed NF in the same NSI. This method may make the time to satisfy the first UE request longer, but can sensibly enhance the resource efficiency.

8 High-level requirements of network slicing

This clause specifies the high-level requirements from the service aspect as well as from the network slicing aspect.

– UE level network functions, e.g., registration management and mobility management, etc., are required to be shared among the multiple network slices.

  NOTE 1 – Some of the shared functions can be global and be used for all network slices, whereas some of them can be shared among the specific slices serving the same users.

– The service level network functions, e.g., session management and data path control, etc., are required to allow to be used as NFs in each network slice.

– The IMT-2020 network is required to instantiate at least one network slice instance (e.g., eMBB) inherited from the characteristics of the SST (e.g., eMBB).

– A UE is recommended to provide all NSTI that it wishes to access to the IMT-2020 network when the UE registers to the network.

– A UE is required to provide a single NSTI indicating a specific network slice when the UE requests the IMT-2020 network to establish a service session.

– The IMT-2020 network is recommended to create a network slice instance based on the NSTI provided by the UE or default network slice instance if the NSTI is not available.

  NOTE 2 – The availability of default network slice instances depends on the IMT-2020 network operator's policy.

– The IMT-2020 network is required to select a network slice instance based on the NSTI provided by the UE, or a default network slice instance if the NSTI is not available.

– The IMT-2020 network is recommended to allocate a default NSTI when a UE subscribes to the network.

– The IMT-2020 network is recommended to add and/or remove the network functions in order to change the configuration of a network slice instance.

– The IMT-2020 network is required to minimize the impact, in changing the configuration of a network slice, on services being provided by itself and other network slices.

Appendix I

Descriptions of core network functions relevant to network slicing

(This appendix does not form an integral part of this Recommendation.)

Following paragraphs, which are relevant to core network functions in IMT-2020 networks, are cited from [ITU-T Y.3102] for supporting consideration of the role of NACF.

I.1 Network access control function (NACF)

The NACF functionalities include registration management, connection management and session management function (SMF) selection.

– Registration management

When a UE accesses the network, NACF provides functionalities to register and de-register the UE with the network and it establishes the user context in the network. In the registration procedure, NACF performs, but is not limited to, network slice instance selection, UE authentication, authorization of network access and network services, network access policy control.

– Connection management

When a registered UE requests network services to the network, NACF provides functionalities to establish and release signalling connections between UE and core network. This includes mobility management functionalities.

– SMF selection

When a session establishment request message is received from UE, NACF performs discovery and selection of the SMF that is the most appropriate to manage the session.

When network slicing is used and a NACF instance, which has received a registration request through a signalling message, cannot serve an appropriate network slice for the UE's request, NACF instance re-allocation is required. Rerouting of the signalling message to the target NACF instance is required during the registration procedure to re-allocate the serving NACF instance including the transfer of the UE context.

Depending on the deployment scenarios, the NACF functionalities in a network slice may be performed in distributed multiple NACF instances in order to minimize the signalling delays. In this case, local NACF instances distributed at the network edge can perform the mobility management functionalities for the (intra-RAT and inter-RAT) handovers. The serving NACF instance notifies UE location to SMF. If user plane function (UPF) re-allocation is required to support mobility, SMF selects a new UPF and performs inter-UPF mobility management. NACF re-allocation between local NACF instances can be performed if necessary.

I.2 Session management function (SMF)

This function provides functionalities to set up the IP or non-IP protocol data unit (PDU) connectivity (i.e., PDU session) for a UE as well as to control the user plane for that connectivity (e.g., selection/re-selection of user plane network functions and user path, enforcement of policies including QoS policy and charging policy). SMF gets policy information related to session establishment from the policy control function (PCF).

SMF also provides IP address management functionalities for allocation and release of the UE's IP address.

I.3 Network function registry function (NFR)

This function provides functionalities to assist the discovery and selection of required network functions. Each network function instance registers itself when instantiated and updates its status (i.e., activation/de-activation) so that NFR can maintain information of the available network function instances.

Multiple instances may be discovered by NFR per discovery request from network functions (for example, NACF uses NFR to select appropriate SMF, ASF and PCF). In such cases, NFR responds to the requesting network function with a list of discovered network functions, network function capabilities and optionally additional selection rules. The requesting network function selects an instance from the list and updates NFR to reflect its selection.

When the discovery of network function instances in different network slices is required, NFR instances in different network slices interact with each other. A typical example is the case of discovery of network functions (e.g., user plane function) in visited public land mobile network (VPLMN) when a UE roams.

In general, each network slice instance has its own NFR, at least logically. In certain cases, e.g., if the network slice instances are in the same administrative domain, a single NFR instance can be shared by multiple network slice instances as shown in Figures 6-1 and 6-2 of [ITU-T Y.3102].

I.4 Network slice selection function (NSSF)

This function provides functionalities to select appropriate network slice instances for a UE. When a UE requests registration with the network, NACF sends a network slice selection request to NSSF with preferred network slice selection information. The NSSF responds with a message including the list of appropriate network slice instances for the UE.

I.5 Registration management (RM)

A single UE can be served simultaneously by multiple network slice instances and a single NACF instance may be shared by the different network slice instances.

The selection of a set of network slice instances for the UE is triggered by the first NACF instance but this may lead to NACF instance relocation. For example, when a NACF instance is not proper to serve the UE's requirements related to a network slice, the NACF instance reroutes the UE registration request message to the appropriate NACF instance.

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