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IETF Network Slice Application in 3GPP 5G End-to-End Network Slice
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Abstract

Network Slicing is one of the core features of 5G defined in 3GPP, which provides different network service as independent logical networks. To provide 5G network slices services, an end-to-end network slice has to span three network segments: Radio Access Network (RAN), Mobile Core Network (CN) and Transport Network (TN). This document describes the application of the IETF network slice framework in providing 5G end-to-end network slices, including network slice mapping in the management, control and data planes.

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1. Introduction

Driven by the new applications, 3GPP introduced the concept of network slicing as a feature of its 5G specification. Such a concept is meant to provide a customized connectivity service with specific capabilities and characteristics. A network slice may include a set of network functions and resources(e.g. computation, storage and network resources). In the context of the IETF, the Network Slice Services are defined in [RFC9543] as a set of connections between a number of Service Demarcation Points (SDPs e.g., CE, PE, or NF), where these connections having specific Service Level Objectives (SLOs) and Service Level Expectations (SLEs) over a common underlay network, with the traffic of one customer being separated from another. The concept of IETF Network Slice Service is conceived as technology agnostic.

Network Slice Services as defined in [RFC9543] are thus specified in terms of the set of SDPs connected to the slice, the type of connectivity among them, and a set of SLOs and SLEs for each connectivity construct.

In [I-D.ietf-teas-ietf-network-slice-nbi-yang], the endpoints are identified by an identifier, with some metrics associated to the connections among them as well as certain policies (e.g., rate limits for incoming and outgoing traffic).

The 5G network slice as defined by 3GPP in [TS-23.501] does not take the transport network slice into consideration. 3GPP introduces the concept of 5G end-to-end network slice service, which is built on top of three network segments: Radio Access Network (RAN), Transport Network (TN) and Core Network (CN). Transport network provides the required connectivity between RAN and CN or inside RAN/CN, with specific performance commitment. The 5G end-to-end network slice services may have distinct topology and performance requirements on the underlying transport network. The transport network should have thus capability to support multiple IETF network slices. The decision about the number of such IETF network slices is deployment specific.

This document focuses on the mapping between 5G network slices and the network slices in underlying Transport Networks. Specifically, the document describes how RFC9543 Network Slice Services can be derived in the context of a 3GPP Network Slice Service in management, control and data planes, including exploring how 3GPP Slice Service parameters are mapped to parameters that are exposed in IETF service data models. It is out of scope of this document to elaborate on the realization of IETF Network Slices as per [RFC9543]. The realizations of RFC9543 network slices are discussed in [I-D.ietf-teas-enhanced-vpn] [I-D.ietf-teas-nrp-scalability] [I-D.ietf-teas-ns-ip-mpls], and a realization model for network slicing in IP/MPLS networks for fulfilling 5G slicing connectivity services is discussed in [I-D.ietf-teas-5g-ns-ip-mpls].

2. Terminology

2.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

This document uses the terms defined in [RFC9543].

The definitions of entities (e.g., DU, CU) or interfaces (e.g., F1) applicable to 3GPP slicing scenarios are provided by 3GPP specifications, such as [TS-38.401]. Similarly, the definitions of entities or interfaces (e.g., Midhaul) applicable to O-RAN slicing scenarios are provided by O-RAN specifications, such as [O-RAN-Arch]. Both 3GPP and O-RAN specifications take precedence over the definitions used in this document for 3GPP and O-RAN concepts.

The following abbreviations are used in this document:

NSC: IETF Network Slice Controller

NSI: Network Slice Instance

NSSI: Network Slice Subnet Instance

S-NSSAI: Single Network Slice Selection Assistance Information

RAN: Radio Access Network

TN: Transport Network

CN: Mobile Core Network

DSCP: Differentiated Services Code Point

CSMF: Communication Service Management Function

NSMF: Network Slice Management Function

NSSM: Network Slice Service Model as defined in {{I-D.ietf-teas-ietf-network-slice-nbi-yang}}

NSSMF: Network Slice Subnet Management Function

IOC: Information Object Class model, defined in 3GPP

In addition to that, the following terms from 3GPP are also used:

* EP_transport: 3GPP Information Object Class (IOC) defined in [TS-28.541] which, represents the logical transport interface of a RAN or CN and includes transport-related information with reference(s) to attachment circuit DM in IETF domain.

* EP_RP: 3GPP IOC defined in [TS-28.622], provided for sub-classing only. This IOC represents an end point of a link used across a reference point between two network entities. Inherited by EP_NgU, EP_F1U, EP_S1U, EP_X2U, etc.

3. 5G End-to-End Network Slice

The scope of a 5G End-to-End Network Slice service discussed in this document is shown in Figure 1. The transport networks (TN) provide the connectivity between and within RAN and CN. To support automated enablement of 5G E2E network slices, multiple controllers are likely to manage 5G E2E network slices across RAN, CN and TN. In addition, a 5G E2E network slice orchestrator is used to coordinate and control the overall creation and life cycle management of 5G E2E network slices across RAN, TN and CN.

```
       <-------------------- 5G E2E Network Slice ------------------->

           |-----------------------------------------------------|
           |           5G E2E Network Slice Orchestrator         |
           |-------|-------------------|-------------------|-----|
                   |                  |                   |
                   v                  v                   v
           |---------------|     |------------|    |--------------|
           |   RAN Slice   |     |    IETF    |    |   CN Slice   |
           |   Controller  |     |    NSC     |    |   Controller |
           |-------|-------|     |-----|------|    |------|-------|
                   |                   |                  |
                   v                   v                  v
        ............................        ..........................
        : RAN                      :        : CN                     :
        :                          :        :                        :
        : |-----|  |----|  |-----| : |----| : |----|  |----|  |----| :
        : | RAN |--| TN |--| RAN |---| TN |---| CN |--| TN |--| CN | :
        : | NFs |  |----|  | NFs | : |----| : | NFs|  |----|  | NFs| :
        : |-----|          |-----| :        : |----|          |----| :
        :                          :        :                        :
        :..........................:        :........................:
```

Figure 1: Scope of 5G End to End Network Slice

Depending on RAN deployment, a single 5G E2E network slice might have one or more IETF network slices. Depends on the operator’s networks, one or more of the following RAN deployments might be used. With different RAN deployments, the scope of TN slice may be different. These RAN deployments are discussed in the following sections:

* Distributed RAN

* Centralized RAN

* Cloud RAN (C-RAN)

3.1. IETF Network Slices in Distributed RAN Deployment

Distributed RAN is the most common deployment of 3GPP RAN networks as shown in Figure 2. RAN is connected to CN using a transport network (TN1).

In this deployment a single 5G E2E network slice might have one or more IETF network slices between RAN and CN networks. In addition, one or more IETF network slices might be present inside the CN network to provide the connectivity between CN network functions (e.g., AMF, CMF and UPF).

```
      <-------------- 5G E2E Network Slice  ------------>
         <---- RS--->          <---------- CS --------->

                   <- INS1 ->        <- INS2 ->
                   (1 or more)      (1 or more)

      .............           ........................
      : RAN       :           : CN                   :
      :           : ........ :         .......       :
      :  |-----|  : :       : : |----| :     : |----| :
      :  | NFs |  : :  TN1 : : | NFs| : TN2 : | NFs| :
      :  |-----|  : :       : : |----| :     : |----| :
      :           : :.......: :         :......:      :
      :...........:           :......................:
   Legend
      INS: IETF Network Slice
      RS: RAN Slice
      CS: Core Slice
```

Figure 2: IETF network slices in distributed RAN deployment

3.2. IETF Network Slices in Centralized RAN Deployment

In general, the RAN network consists of network functions for processing the radio signal and transmitting/receiving the radio signal. As shown in Figure 3, in Centralized RAN deployment, two groups of network functions exit; NFs1 and NFs2 where NFs2 processes the carrier signal and is connected to the transport network and NFs1 transmit and receive the radio signal that is transmitted over the air from and to the end user equipment (UE). In Centralized RAN, network functions NFs1 and NFs2 are separated by a transport network TN3 called fronthaul network (FH). In this deployment a 5G E2E network slice contain of RAN and CN slices and one or more IETF network slices INS1, INS2 and INS3. INS1 and INS2 are identical to the IETF network slices shown in Figure 2. However, the IETF network slices INS3 needed across RAN network to provide the connectivity among NFs1 and NFs2.

```
         <-------------------- 5G E2E Network Slice  ------------------>
           <-------- RS --------->          <---------- CS --------->

                <- INS3 ->       <- INS1 ->         <- INS2 ->
               (1 or more)      (1 or more)        (1 or more)

         .........................          ...........................
         : RAN                   :          : CN                      :
         :        .......        : ........ :          .......        :
         : |----| :     : |----| : :      : : |-----| :     : |-----| :
         : |NFs1| : TN3 : |NFs2| : : TN1  : : | NFs | : TN2 : | NFs | :
         : |----| :(FH) : |----| : : (BH) : : |-----| :(BH) : |-----| :
         :        :.....:        : :......: :         :.....:         :
         :.......................:          :.........................:
      Legend
        INS: IETF Network Slice
        RS: RAN Slice
        CS: Core Slice
        FN: Fronthaul IETF network
        BH: Backhaul IETF network
```

Figure 3: IETF network slices in centralized RAN deployment

3.3. IETF Network Slices in Cloud RAN deployment (C-RAN)

In a Cloud RAN deployment, the network function NF2 is further disaggregated into real-time and non-real-time components. As shown in Figure 4, these disaggregated components are called CU (Central Unit) and DU (Distributed Unit) where they are connected by a new network called Midhaul network (MH).

In this deployment 3GPP network slice contains not only RAN and Core slices but IETF network slices INS1, INS2, INS3 and INS4. IETF network slices INS1, INS2 and INS3 are similar to those in Figure 3. An additional IETF network slice INS4 is used to connect the DUs to CUs through F1 interfaces.

```
     <---------------------- 5G E2E Network Slice  -------------------->
       <-------------- RS -------------->          <------- CS ------>

            <- INS3 ->      <- INS4 ->   <- INS1 ->     <- INS2 ->
            (1 or more)    (1 or more)  (1 or more)    (1 or more)

     ......................................        .....................
     : RAN                                :        :CN                 :
     :       .......       ......         : ...... :       .....       :
     : |----| :     : |---| :     : |---| : :    : : |---| :   : |---| :
     : |NFs1| : TN3 : |DU | : TN4 : |CU | : : TN1: : |NFs| :TN2: |NFs| :
     : |----| :(FH) : |---| : (MH): |---| : :(BH): : |---| :   : |---| :
     :        :.....:       :.....:       : :....: :       :...:       :
     :....................................:        :...................:
  Legend
    INS: IETF Network Slice
    RS: RAN Slice
    CS: Core Slice
    FN: Fronthaul IETF network
    MN: Midhaul IETF network
    BH: Backhaul IETF network
    DU: Distributed Unit
    CU: Central Unit
```

Figure 4: IETF network slices in cloud RAN deployment (C-RAN)

For the sake of illustration, the following sections in this document all consider the TN slice between RAN and CN. Other IETF network slice cases are similar.

3.4. Relationship Between IETF Network Slices and 3GPP Network Slices

Based on the Architecture of an IETF Network Slice and Interface of IETF Network Slice Management Architecture defined in [RFC9543], Figure 5 shows the relationship between 3GPP controllers and IETF Network Slice Controller.

```
       +---------------------+
       |         CSMF        |
       +----------|----------+
                  |                    +------------------------+
       +---------------------+         |  5G E2E Network Slice  |
       |         NSMF        |         |      Orchestrator      |
       +---------------------+         +------------------------+
             /    |    \                            |
            /     |     \           IETF Network Slice Service Interface
           /      |      \                          |
  +---------++---------++---------+    +------------------------+
  |    AN   ||    TN   ||   CN    |    |   IETF Network Slice   |
  |   NSSMF ||   NSSMF ||  NSSMF  |    |     Controller (NSC)   |
  |         ||         ||         |    +------------------------+
  +---------++---------++---------+   Network configuration interface
       |          |          |                      |
       |          |          |         +------------------------+
       |          |          |         |    Network Controllers |
       |          |          |         +------------------------+
       |          |          |                      |
       |          |          |                      |
   .?????.    .???????.    .???????.            .?????????.
  ?  5G   ?  ?  IETF   ?  ?   5G    ?          ?   IETF    ?
 (   RAN   )(  Network  )(   Core    )        (   Network   )
  ‘.     ,’  ‘.       ,’  ‘.       ,’          ‘.         ,’
    ‘???’      ‘?????’      ‘?????’              ‘???????’
```

Figure 5: Relationship between 3GPP domain controllers and IETF Network Slice Controller

An example of 5G E2E Network Slice is showed in Figure 6. Each E2E network slice contains RAN slice, CN slice and one or more IETF network Slices. 3GPP identifies each E2E network slice using an integer called S-NSSAI. In Figure 6 there are three instances of E2E network slices which are identified by S-NSSAI 01111111, 02222222 and 03333333, respectively. Each instance of E2E network slice contains AN slice, CN Slice and one or more IETF network slices. For example, E2E network slice 01111111 has AN Slice instance 4, CN Slice instance 1 and IETF network slice 6. Note that 3GPP does not cover the IETF network slice. Details of IETF network slice could be found in [RFC9543].

Note that 3GPP uses the terms NSI and NSSI which are a set of network function and required resources (e.g. compute, storage and networking resources) which corresponds to network slice Instance, whereas S-NSSAI is an integer that identifies the E2E network slice.

```
                  +-----------+ +-----------+  +-----------+
                  |  S-NSSAI  | |  S-NSSAI  |  |  S-NSSAI  |
                  |  01111111 | |  02222222 |  |  03333333 |
                  +---|-------+ +---|---|---+  +----|------+
                      |  +----------+   |           |
                      V  V              V           V
                   **********    **********    **********
      Core         * NSSI 1 *    * NSSI 2 *    * NSSI 3 *
      Network      **********    **********    **********
                        \              \             /
                         \              \           /
                         +-----+       +-----+    +-----+
      Transport          | IETF|       | IETF|    | IETF|
      Network            | NS 6|       | NS 7|    | NS 8|
                         +-----+       +-----+    +-----+
                             \              \   /
                              \              \ /
        Radio                    **********   **********
       Access                    * NSSI 4 *   * NSSI 5 *
       Network                   **********   **********
```

Figure 6: 5G End-to-End Network Slice and its components

4. 5G E2E Network Slice Mapping Procedure

4.1. 5G E2E Network Slice Mapping Identifier

The following network slice related identifiers in management, control and data planes play an important role in the end-to- end network slice mapping:

* Single Network Slice Selection Assistance Information (S-NSSAI): the end-to-end network slice identifier, which is defined in [TS-23.501]; S-NSSAI is used during 3GPP network slice signaling process.

* Network Slice Service identifier : An identifier allocated by IETF Network Slice Controller (NSC) in the management plane. See [I-D.ietf-teas-ietf-network-slice-nbi-yang].

4.2. 5G E2E Network Slice Mapping Procedure

This section provides a general procedure of network slice mapping:

```
                   +-----------------+
                   |       NSMF      |
                   +-----------------+
        +----------|     S-NSSAI     |----------+
        |          |(e.g., 011111111)|          |
        |          +-----------------+          |
        |                   |                   |
        V                   V                   V
 +-------------+ +---------------------+ +-------------+
 |  RAN NSSMF  | |       IETF NSC      | |   CN NSSMF  |
 +-------------+ +---------------------+ +-------------+
 |   RAN Slice | | IETF Network Slice  | |   CN Slice  |
 | Identifier  | |     Identifier      | | Identifier  |
 | (e.g., 4)   | |     (e.g., 6)       | | (e.g., 1)   |    Management
 +-------------+ +---------------------+ +-------------+      Plane
      |           |                   |          |      -----------------
      |           |                   |          |
      V           V                   V          V      -----------------
   +-----+   +-----+             +-----+    +------+        Data
   | RAN |---|  PE |-----...-----| PE  |----|  CN  |        Plane
   +-----+   +-----+             +-----+    +------+
```

Figure 7: Relationship between IETF and 3GPP Network Slice Management

1. 3GPP NSMF receives the request from 3GPP CSMF for allocation of a network slice instance with certain characteristics.

2. Based on the service requirement, 3GPP NSMF acquires requirements for the end-to-end network slice instance, which is defined in Service Profile (section 6.3.3 of [TS-28.541]).

3. Based on Service Profile, 3GPP NSMF determines the network function and the required resources in AN, CN and TN networks. It also assigns the unique S-NSSAI ID.

4. 3GPP NSMF sends a request to AN NSSMF for creation of AN Slice, which is out of the scope of this document.

5. 3GPP NSMF sends a request to CN NSSMF for creation of CN Slice, which is out of the scope of this document.

6. 3GPP NSMF sends a request to an IETF NSC (acting as an NSSMF for transport network, from the perspective of the 3GPP Management System)) for creation of a RFC9543 Network Slice service. The request contains attributes such as endpoints (based on the information from EP_Transport), required SLA along with other IETF network slice attributes.

7. The IETF NSC realizes the IETF Network Slice which satisfies the requirements of the [RFC9543] Network Slice Service requested between the specified endpoints (RAN/CN edge nodes). The IETF NSC might assign an IETF Network Slice Service ID and send it to 3GPP NSMF.

8. The 3GPP NSMF could maintain the mapping relationship between S-NSSAI and IETF Network Slice Service ID.

5. 5G E2E Network Slice Mapping in Management and Control Planes

The transport network management Plane maintains the interface between 3GPP NSMF and TN NSSMF. It is supposed to satisfy the following requirements:

1. Build up mapping relationship between NSI identifier and RFC9543 Network Slice Services;

2. Guarantee that IETF network slice could satisfy the SLA requirements with the transport network connection between AN and CN;

3. The requirements for 5G E2E network slice could be specified in IETF network slice northbound interface.

In order to provide slice connectivity constructed by means of IETF network slices it is necessary to build up mapping relationship between two different endpoints, as depicted in Figure 8:

* Mapping from EP_Transport of 3GPP network slice side (as defined by [TS-28.541]) to the CE endpoint from IETF network slice side (as defined in [RFC9543]). IETF Network Slice Controller (NSC) will receive the set of CE endpoints to be interconnected as input for network slice services defined in [RFC9543].

* Mapping from CE endpoints to PE endpoints. The endpoint at PE side should be elicited by the IETF NSC, in order to establish connectivity which could satisfy the customer request, according to the SLOs and SLEs received from the higher level system.

```
        3GPP concern

       EP_RP_left                                 EP_RP_right
          |                                                       |
        --|--------                                            ---|-----
          |      /                                            /   |
          x     /                                            /    x
               O EP_Transport_left       EP_Transport_right O
              /A                                           /A
             / |                                          / |
        -----  |                                         ---|-------
               |                                            |
               |                                            |
        .......|............................................|..........
               |                                            |
               |                                            |
               |                                            |
        -------|--       ----------            ----------   |  -------
               | /      /        /  _____     /        /    | /
               V/      /        /  (    )    /        /     V/
               O<---->O        0==(      )==0        O<---->O
              /      /        /    (____)  /        /      /
             /      /        /            /        /      /
        -----      ----------            ----------      ----------
        CE_left     PE_left              PE_right       CE_right

        IETF concern
```

Figure 8: conceptual view on 3GPP and TN end-points

The examples in Section 7 will show how the connection between network slice from endpoints at both 3GPP and IETF side can be established.

5.1. Mapping EP_transport to IETF NS CE Endpoints

The 3GPP Management system provides the EP_Transport Information Object Class (IOC) to extend slice awareness to the transport network. This IOC carries parameters that describe the transport endpoints associated with the 3GPP-managed functions (detailed in the EP_Application IOC). These parameters include:

* IP Address: The IP address of the transport endpoint.

* Additional Identifiers: Optional identifiers that further define the logical interface, such as VLAN tag, MPLS label, Segment Routing (SR) SID, etc.

* QoS Profile (Optional): A set of parameters specifying the Quality of Service (QoS) requirements for the slice.

The parameters from the EP_Transport IOC (representing the 3GPP domain) needs to be translated into the corresponding parameters for the CE within the IETF network slice. This translation process can be straightforward in certain scenarios. In such cases, the information from the EP_Transport IOC can be directly passed to the IETF Network Slice Subsystem (NSS) through the standardized Network Slice Services Interface defined in RFC9543. However, additional information might be required which have not been specified in 3GPP standards, e.g., subnet mask for the IP address).

For example, when 3GPP-managed functions reside on dedicated monolithic network elements, the IP address in the EP_Transport IOC could directly map to the IP address of the corresponding interface.

The mapping process becomes more complex when dealing with virtualized 3GPP-managed functions. These functions can be instantiated on general-purpose servers or within data centers. In these scenarios, additional information are needed to identify the corresponding CE endpoint for example with other parameters defined in EP_transport, including:

* Combined Identification: The NS CE endpoint might be identified by a combination of the IP address and additional information like VLAN tag, MPLS label, or SR SID. This combination helps distinguish specific logical interfaces.

* Next Hop Information: The next hop router information, as viewed by the 3GPP entity within the slice, could provide hints for determining the slice endpoint at the other side of the slice boundary.

* QoS Profile: The QoS profile, if present, helps configure the PE endpoint to meet the Service Level Objectives (SLOs) for the connection between the CE slice endpoints.

5.2. Mapping IETF NS CE to PE Endpoints

As outlined in [RFC9543], an IETF Network Slice can have various potential endpoint positions, as reflected in Figure 9. The information passed to the IETF Network Slice Controller (NSC) regarding endpoints is relative to the CE side, which is the perspective of the slice customer (i.e., the 3GPP Management System managing the 3GPP-managed functions). Based on this information, the IETF NSC needs to infer the corresponding endpoint on the Provider Edge (PE) side. This inference is crucial for establishing the desired connectivity constructs with the specified Service Level Objectives (SLOs) in the request.

Since the IETF slice request process is technology-agnostic, the identification of PE side endpoints should rely on generic information passed through the standardized Network Slice Service Model (NSSM as defined in [I-D.ietf-teas-ietf-network-slice-nbi-yang]). This generic information, combined with the knowledge of the network topology and available resources, will allow the IETF NSC to determine the appropriate PE endpoint for each CE endpoint, ensuring a successful network slice instantiation.

```
              |<---------------------- (1) ---------------------->|
              |                                                   |
              | |<-------------------- (2) -------------------->| |
              | |                                               | |
              | |        |<----------- (3) ----------->|        | |
              | |        |                             |        | |
              | |        |  |<-------- (4) -------->|  |        | |
              | |        |  |                       |  |        | |
              V V   AC   V  V                       V  V   AC   V V
          +-----+   |    +-----+                 +-----+    |   +-----+
          |     |--------|     |                 |     |--------|     |
          | CE1 |   |    | PE1 |. . . . . . . . .| PE2 |    |   | CE2 |
          |     |--------|     |                 |     |--------|     |
          +-----+   |    +-----+                 +-----+    |   +-----+
             ^              ^                       ^              ^
             |              |                       |              |
             |              |                       |              |
          Customer       Provider                Provider       Customer
          Edge 1         Edge 1                  Edge 2         Edge 2

        (1) SDPs within the CE (e.g. buffers or queues on the outgoing interfaces)
        (2) SDPs at the Attachment Circuit
        (3) SDPs at the customer-facing ports on the PEs
        (4) SDPs within the PE (e.g. destination IP addresses, port numbers)
```

Figure 9: IETF Service Demarcation Points

6. Methods for Mapping Between 3GPP E2E Network Slice and IETF Network Slice

Referring to Figure 2, Figure 3 and Figure 4, an end-to-end network slice might have one or more IETF network slices. Figure 10 is a general representation of any of transport networks in 5G end-to-end network slice where the IETF network slice INS_a provides the connectivity between network functions NF1 and NF2 to satisfy the specific SLO/ SLE. For example, Figure 10 could represent IETF network slice INS1 of Figure 4 where connectivity needed between network functions CU and UPF or it could represent IETF network slice INS4 between network functions DU and CU.

Suppose the network function NF1 sends the traffic to NF2. The data plane mapping is mainly addresses how the identification of 3GPP network slice is conveyed and represented on data path, and how the provider network PE nodes map the traffic from context of 5G end-to-end network slice to the [RFC9543] network slice services. It is crucial for PE nodes to be able to map the traffic to the appropriate IETF network slice so as to enforce the SLO/SLE policy.

```
          <------ IETF Network Slice Service INS_a ------>

                 AC         .-------.          AC
                 |        ,'         '.        |
                 |      ,'             '.      |
       --------  V   -------         -------   V   --------
       |      |      |     |         |     |       |      |
       | NF1  |------| PE1 |         | PE2 |-------| NF2  |
       |      |------|     |         |     |       |      |
       --------      ------- Provider -------       --------
                         '.  Network  ,'
                           '.       ,'
                             -------
```

Figure 10: Typical IETF Network Slice in 3GPP Network between NF1 and NF2

To provide an overview of various mechanisms of mapping 5G E2E network slice to IETF network slices, we focus on IETF network slice INS1 in Figure 4 where IETF network slice INS1 provides the connectivity between network functions CU and UPF. Figure 11 shows this scenario. Although the various mapping techniques considered in this section is for IETF network slice INS1, they are all applicable to other IETF network slices of Figure 2, Figure 3 and Figure 4, i.e., INS2, INS3 and INS4.

The IETF network slice INS1 provides the connectivity between service demarcation points SDP1 and SPD2. These SDPs are the N3 interfaces on CU and UPF, respectively. As shown in Figure 11(A) and Figure 11(B), the SDPs could be either loopback interfaces or a physical interfaces on CU and UPF network functions. For simplicity case (A) is considered in this section although the various mapping methods are identically applicable to both cases (A) and (B).

```
             <-------------------- INS1 ------------------>

            SDP1                                        SDP2
          (N3 I/F)                                    (N3 I/F)
             |                 .-------.                  |
             |               ,'         '.                |
             v             ,'             '.              V
         --------       -------          -------       --------
         |   O  |       |     |          |     |       |  O   |
         |      |       | PE1 |          | PE2 |       |      |
         |  CU  |       |     |          |     |       |  UPF |
         --------       ------- Provider -------       --------
                            '.  Network  ,'
                              '.       ,'
                                -------
                                  (A)


                <----------------- INS1 --------------->

               SDP1                                  SDP2
             (N3 I/F)                              (N3 I/F)
                |              .-------.              |
                |            ,'         '.            |
                v          ,'             '.          V
         --------       -------          -------       --------
         |      *       |     |          |     |       *      |
         |      |       | PE1 |          | PE2 |       |      |
         |  CU  |       |     |          |     |       |  UPF |
         --------       ------- Provider -------       --------
                            '.  Network  ,'
                              '.       ,'
                                -------
                                  (B)
       Legend:
        <---> IETF Network Slice Service between SDP1 and SDP2
         *  SDP (N3 interface as CU IP interface)
         O  SDP (N3 as CU loopback interface)
```

Figure 11: Representation of a Typical IETF Network Slice between CU and UPF

Various techniques can be used to map the IETF network slice to 5G E2E network slice. The section covers the following techniques which can be used for mapping between 5G E2E network slice and [RFC9543] network slice services. Note that these techniques might also be used by IETF network slice controller (NSC) to influence the realization of the IETF network slice services as well. The latter case is out of scope of the current draft:

* Mapping based on VLAN

* Mapping based on MPLS label or SR-MPLS SID

* Mapping based on SRv6 SID

* Mapping based on Policy Based Routing (PBR)

* Mapping based on UDP source port

It should be noted that the first three mapping mechanisms are briefly mentioned in [TS-28.541].

6.1. Mapping based on VLAN ID

In some scenarios, it would be possible for provider edge (PE) nodes to infer the identification of the 5G E2E network slices from the VLAN ID carried in the data path traffic, and map the traffic to the corresponding IETF network slice. As shown in Figure 12, the IETF Network slice INS1 between network functions CU and UPF can be mapped using the VLAN ID. In this scenario, the VLANs assigned by network functions CU and UPF are used for the handoff to the provider network.

Refer to section 4.1 of [I-D.ietf-teas-5g-ns-ip-mpls] for details of this solution and how it is realized by provider network.

```
            <-------------------- INS1 ------------------->

              VLAN Handoff  IP/MPLS Services
                    |              |
                    |              |
           N3 I/F   |          .---|---.                N3 I/F
             |      |        ,'    |    '.                |
             V      V      ,'      V      '.              V
         --------       -------          -------       --------
         |   O..........+======================+...........O  |
         |      |       | PE1 |          | PE2 |       |      |
         | CU   |       |     |          |     |       | UPF  |
         --------       ------- Provider -------       --------
                            '.  Network  ,'
                              '.       ,'
                                -------

                                  (A)
       Legend:
         O  SDP (N3 interface)
         +  Access points to provider network
         ... VLAN hand-off
         === IP/MPLS transport service in provider network
             (i.e., realization of INS1)
```

Figure 12: VLAN based IETF Network Slice Mapping

6.2. Mapping based on MPLS Label or SR-MPLS SID

This section describes another solution for mapping the 5G E2E network slice traffic to IETF network slices based on MPLS/SR-MPLS labels/SIDs. The labels/SIDs carried in the packets sent from CU to UPF can be used by the provider edge (PE) nodes to infer the identification of the 5G E2E network slices and map the packet to the corresponding IETF network slice. Figure 13 shows an example where the 5G E2E network slice is mapped to IETF network slice INS1 using the MPLS label or SR-MPLS SID. In this case, the MPLS label or SR-MPLS SID is used for the handoff to the provider network.

Refer to section 4.3 of [I-D.ietf-teas-5g-ns-ip-mpls] for details of this solution and how it is realized by provider network.

```
            <-------------------- INS1 ------------------->

             tunnel (represented by MPLS label or SR-MPLS SID)
                    |
                    |
           N3 I/F   |          .--------.               N3 I/F
             |      |        ,’         ‘.                |
             V      V      ,’             ‘.              V
         --------       -------          -------       --------
         |   *=============================================*  |
         |      |       | PE1 |          | PE2 |       |      |
         | CU   |       |     |          |     |       | UPF  |
         --------       ------- Provider -------       --------
                            ‘.  Network  ,’
                              ‘.       ,’
                                -------
                                  (A)
       Legend:
            * SDP1 and SPD2 (N3 Address)
            === tunnel between SDP1 and SDP2 (MPLS or SR-MPLS)
```

Figure 13: MPLS label or SR-MPLS SID based IETF Network Slice Mapping

6.3. Mapping based on SRv6 SID

This section describes a solution for mapping the 5G E2E network slice traffic to IETF network slices based on SRv6 SIDs. This solution is similar to the mapping based on MPLS label or SR-MPLS SID but using SRv6 tunnels. As shown in Figure 14, the SRv6 SIDs is added by CU or UPF to the data path traffic between SDP1 and SPD2. The SRv6 SIDs can be used by the provider edge (PE) nodes to infer the identification of the 5G E2E network slices and map the traffic to the corresponding IETF network slice.

In this solution, the identification of the 5G E2E network slice may be embedded into IPv6 SIDs, where the 32-bit 3GPP network slice identification is mapped into the 128-bit IPv6 SID, thus the SRv6 SID is used for the handoff to the provider network.

Refer to section 4.2 of [I-D.ietf-teas-5g-ns-ip-mpls] for details of this solution and how it is realized by the provider network.

```
            <-------------------- INS1 ------------------->

               SRv6 tunnel (represented by SRv6 SID)
                    |
                    |
           N3 I/F   |          .--------.              N3 I/F
             |      |        ,'          '.                |
             V      V      ,'              '.              V
         --------       -------          -------       --------
         |   *=============================================*  |
         |      |       | PE1 |          | PE2 |       |      |
         | CU   |       |     |          |     |       | UPF  |
         --------       ------- Provider -------       --------
                            '.  Network  ,'
                              '.       ,'
                                -------

                                  (A)
       Legend:
            * SDP1 and SPD2 (N3 address)
            === SRv6 tunnel between SDP1 and SDP2
```

Figure 14: SRv6 SID based IETF Network Slice Mapping

6.4. Mapping based on Policy Based Routing (PBR)

This section provides a solution for mapping the 3GPP E2E network slice traffic to IETF network slices. As shown in Figure 15, in some deployments of the 5G network slices, it would be possible for provider edge (PE) nodes to infer the identification of the 3GPP E2E network slice from the content of the IP data packet sent between CU and UPF. In these cases, the PE nodes can identify the 5G E2E network slice using any combination of the following attributes and then map them to RFC9543 network slice services:

* Source N3 IP address

* Destination N3 IP address

* Ingress interface

* DSCP

* Other information in the packet (at IP/MPLS layer or upper layers such as UDP/TCP)

Once the PE nodes receives the IP packets, it may apply infer the context of the 5G E2E network slice and then apply a policy-based routing (PBR) to the packet to map the traffic of specific 5G E2E network slice to the corresponding IETF network slices in the provider network. The details of this solution is beyond scope of this draft.

```
            <-------------------- INS1 ------------------->

                       PBR        INS1        PBR
                enforcement    realization    enforcement
                        |          |           |
                        |          |           |
           N3 I/F       |      .---|---.       |        N3 I/F
             |          |    ,'    |    '.     |          |
             V          V  ,'      V      '.   V          V
         --------       -------          -------       --------
         |   O..........+======================+..........O   |
         |      |       | PE1 |          | PE2 |       |      |
         | CU   |       |     |          |     |       | UPF  |
         --------       ------- Provider -------       --------
                            '.  Network  ,'
                              '.       ,'
                                -------
       Legend:
         O  SDP ((N3 interface)
         +  Access points of IP/MPLS Services when PBR is enforced
         === IP/MPLS realization of the IETF network slice
```

Figure 15: Policy Based Routing (PBR) based IETF Network Slice Mapping

6.5. Mapping based on UDP Source Port

This section provides another solution for mapping the 5G E2E network slice traffic to IETF network slices. In some deployments of the 5G E2E network slices, it might be possible for PE nodes to infer the identification of the 3GPP E2E network slice based on the information of the GTP tunnels. As shown in Figure 16, the source UDP port of the data packet may be used to infer the identification of 5G E2E network slices. In this case, a mapping table between the identification of 5G network slice and the source UDP port needs to be maintained by network functions CU, UPF and the PE nodes.

The details of this solution is described in [I-D.ietf-dmm-tn-aware-mobility].

```
           <-------------------- INS1 -------------------->
            GTP tunnels
                    |
                    |
           N3 I/F   |          .-------.             N3 I/F
             |      |       ,'          '.             |
             V      V     ,'              '.           V
         --------       -------         -------       --------
         |   *=============================================*  |
         |   *=============================================*  |
         |      |       | PE1 |         | PE2 |       |       |
         | CU   |       |     |         |     |       | UPF   |
         --------       ------- Provider -------       --------
                            '.  Network  ,'
                              '.       ,'
                                -------
      Legend:
        *  SDP (N3 address)
           === GTP tunnels in context of IETF network slice INS1
```

Figure 16: UDP source port solution for IETF Network Slice Mapping

7. IETF Network Slice request through IETF Network Slice NBI

As discussed in [RFC9543], to fulfill IETF network slices and to perform monitoring on them, an entity called IETF Network Slice Controller (NSC) is required to take abstract requests for IETF network slices and realize them using suitable underlying technologies. An IETF Network Slice Controller is the key building block for control and management of the IETF network slice. It provides the creation/modification/deletion, monitoring and optimization of transport Slices in a multi-domain, a multi-technology and multi-vendor environment.

Figure 17 shows the NSC and its NBI interface for 5G, defined as IETF Network Slice Service Interface in [RFC9543]. Draft [I-D.ietf-teas-ietf-network-slice-nbi-yang] a addresses the service yang model of such NSC NBI interface for all network slicing use-cases.

```
                  +------------------------------------------+
                  |            5G Customer (Tenant)          |
                  +------------------------------------------+
                                     A
                                     |
                                     V
                  +------------------------------------------+
                  |    5G E2E Network Slice Orchestrator     |
                  +------------------------------------------+
                                     A
                                     | IETF Network Slice Service Interface
                                     V
                  +------------------------------------------+
                  |    IETF Network Slice Controller (NSC)   |
                  +------------------------------------------+
                                     A
                                     | Network Configuration Interface
                                     V
                  +------------------------------------------+
                  |          Network Controller(s)           |
                  +------------------------------------------+
```

Figure 17: Interfaces of the IETF Network Slice Controller

As discussed in [RFC9543], the main task of the IETF Network Slice Controller is to map abstract IETF network slice requirements from NBI to concrete technologies on SBI and establish the required connectivity, and ensure that required resources are allocated to IETF network slice. There are a number of different technologies that can be used on SBI including physical connections, MPLS, TSN, Flex-E, PON etc. If the underlay technology is IP/MPLS/Optics, any IETF models can be used during the realization of the IETF network slice.

There are no specific mapping requirements for 5G. The only difference is that in case of 5G, the NBI interface contains additional 5G specific attributes such as customer name, mobile service type, 5G E2E network slice ID (i.e. S-NSSAI) and so on (See Section 6). These 5G specific attributes can be employed by IETF Network Slice Controller during the realization of 5G IETF network slices on how to map NBI to SBI. They can also be used for assurance of 5G IETF network slices. Figure 18 shows the mapping between NBI to SBI for 5G IETF network slices.

```
                     | (1) NBI: Request to create/modify/delete
                     |          5G IETF Network Slice
                     V
           +----------------------+
           |  IETF Network Slice  | (2) Mapping between technology
           |    Controller (NSC)  |     agnostics NBI to technology
           +----------------------+     specific SBI
                    ^ ^ ^
                    | | |
                |---| | |---|  (3) SBI: Realize 5G IETF Network Slice
                |     |     |      by using various IETF models for
                V     V     V      services, tunnels and paths
           +----------------------+
           |       Network        |-+
           |     Controller(s)    | |-+
           +----------------------+ | |
             +----------------------+ |
               +----------------------+
```

Figure 18: Relationship between transport slice interface and IETF Service/Tunnels/Path data models

The following figure illustrates the relationship between 3GPP or ORAN subsystems connected through IETF TN domain. After the analysis of 3GPP Generic Network Resource Models (NRM) of [TS-28.540] Rel 17, [TS-28.541] Rel 17 and [TS-28.622] Rel 16 the following objects have been identified as entities on which the decision of mapping to IETF TN slices can be made. These available delineators of network slices, represented by the arrows in the figure, are accessible in IETF domain and possible to be treated as triggers for decision of mapping 3GPP slice to IETF TN slice.

Option (1) - the object class of 3GPP/ORAN subsystem is EP_Transport, [TS-28.541] clause 6.3.18, representing a list of attributes including IETF-related parameters, directly exposed to transport network domain:

* ipAddress -- an IP address assigned on the 3GPP/ORAN subsystem side of the link to TN.

* logicInterfaceType and logicInterfaceId -- in current release it is an ID of the VLAN and encapsulation type is 802.1Q

These parameters can program the slice separation and be mapped to an IETF slice.

By instantiating EP_Transport per slice on 3GPP/ORAN subsystem the slicing may be implemented and mapped on slices in IETF TN domain. In this case EP_Transport parameters may be mapped to draft-ietf-teas-ietf-network-slice-nbi-yang data model objects. This option is described in the following example in current document.

Option (2) - the object class is EP_RP ([TS-28.622] clause 4.3.11), EP_F1U ([TS-28.541] clause 4.3.13), EP_NgU ([TS-28.541] clause 4.3.11), EP_N3 ([TS-28.541] clause 5.3.20), representing the 3GPP link and association between 3GPP/ORAN subsystems. These attributes are not exposed directly to IETF TN domain and can be treated as loopbacks behind the link, defined in EP_Transport object class. Instantiation and manipulation of EP_RPs per slice may be mapped on slices in IETF TN domain, while link defined by parameters of EP_Transport may remain the same. This delineation by loopbacks is adding secondary axis of flexibility to network slicing and needs to be mapped to [I-D.ietf-teas-ietf-network-slice-nbi-yang] data model with different logic that delineation in option (1).

```
 +------------------------+                   +------------------------+
 ||3GPP or ORAN subsystem |Provider Provider  |3GPP or ORAN subsystem  |
 |(e.g. (O)-DU)           |Edge 1   Edge 2    |(e.g. (O)-CU-UP)        |
 |+----------------------+|    +--+   +--+    |+----------------------+|
 ||Bearer                ||    |  |   |  |    ||Bearer                ||
 ||    +------+ +-------+||  | |  =====  | |  ||+-------+ +------+    ||
 ||    |EP_RP | |EP_Tran|||  | |PE|   |PE| |  |||EP_Tran| |EP_RP |    ||
 ||    |EP_F1U|-| sport X++--+-|  =====  |-+--|X  sport |-|EP_F1U|    ||
 ||    +---A--+ +---A---+||  | |  |   |  | |  |+----A---+ +-A----+    ||
 |+--------+-------+----+|  | +--+   +--+ |  |+----+-------+-------- +|
 +---------+-------+-----+  |            |  +-----+-------+----------+
           |       |        |            |        |       |
          (2)     (1)       AC           AC      (1)     (2)
    Customer Edge 1                                Customer Edge 2
```

Figure 19: Slice mapping options analysis based on 3GPP NRM

These basic options represent possible implementation options of objects and parameters Operator may use to instantiate slices and correlate them with network slices in IETF TN domain to ensure SLA and SLO per slice.

Since 3GPP Generic Network Resource Models are not limiting use of these object classes and not mandating roles and mapping procedures, any combination of (1), (2) and (3) may be implemented in real slicing scenario.

(1) The use of slicing based on EP_Transport instantiation may be favorable due to direct exposure of connectivity parameters to IETF TN domain. However, there are currently gaps in the NRM that may affect this option:

* The NRM Rel. 17 lacks definitions and object class structures for DC or DC-fabric implementations of RAN or CN instances.

* The attribute in EP_Transport qosProfile has no relation to clauses 5.3.84 QoSData and 5.3.79 FiveQiDscpMapping and cannot be extracted or mapped to SLO/SLE constructs as the information is not available in the IETF domain.

* The destination of the traffic may potentially be extracted from EP_RP ([TS-28.622] clause 4.3.11), but this information is not accessible in the IETF domain, so it cannot be extracted or mapped to communication type and connectivity constructs.

* Redundancy of EP_Transports is an open topic for failover and protection mechanisms

(2) The option of using a common EP_Transport and multiple EP_RP with unique IP addresses may be suitable for DC and DC-Fabric implementations where EP_Transport establishes connectivity to the IETF TN domain and EP_RPs serve as virtual instance loopbacks. However, the lack of direct exposure of IP addresses and slice demand parameters in the IETF domain may make this slicing option challenging to implement. Currently, the following gaps have been identified:

* EP_Transport object class does not define a mechanism for active communication of EP_RP loopbacks to the IETF ingress PE device (e.g., no PE-CE protocols)

* Redundancy for EP_Transports is still an open topic for failover and protection mechanisms, with the added complexity of EP_RP loopback switchover

* Pre-installed policies in the IETF TN domain for pre-defined EP_RP loopbacks may result in network overprovisioning (e.g., PBR, policies, service-match-criteria)

* The absence of a common toolset for monitoring the existence and activity of EP_RP loopbacks may hinder root cause analysis and troubleshooting.

Following subsections present several examples for illustrating the mapping of 3GPP objects to IETF NSSM model [I-D.ietf-teas-ietf-network-slice-nbi-yang].

7.1. Example according to CE-mode (OPTION 1)

This example considers the request of a slice for realizing the F1-U [3GPP [TS-38.470] interface between a DU and a CU-UP elements (i.e., INS4 in previous Figure 4). Note that the example is equally valid for the realization of any other case.

The example follows the CE-mode as described in Figure 20.

```
     +-----+        Association between X and Y              +-----+
     |     |    according to 3GPP (i.e., NgU/N3 interface)   |     |
     | gNB |<----------------------------------------------->| UPF |
     |     |                                                 |     |
     +-----+                                                 +-----+

     +-----+       Association between DU and CU-UP          +-----+
     |     |            (i.e., F1-U interface)               |     |
     |  DU |<----------------------------------------------->|CU-UP|
     |     |                                                 |     |
     +-----+                                                 +-----+
                        \__________  __________/
                                   \/
       SDP1                                                  SDP2
    (with CE1 parameters)                       (with CE2 parameters)
       o<----------------- IETF Network Slice ---------------->o
       +                                                       +
       +|<------------------------- S1 ---------------------->|+
       +|                                                     |+
       +|                |<------- T1 ----->|                 |+
       +|                v                  v                 |+
       +v            +----+                 +----+           v+
    +--+--+    |     | PE1|==================| PE2|     |    +-+---+
    |  +  |    |     |    |                  |    |     |    | +   |
    |  o  X----------X    |                  |    X----------X o   |
    |     |    |     |    |                  |    |     |    |     |
    +-----+    |     |    |==================|    |     |    +-----+
               AC    +----+                  +----+     AC
    Customer         Provider                Provider        Customer
    Edge 1           Edge 1                  Edge 2          Edge 2
```

Legend:
O: Representation of the IETF network slice endpoints (SDP)
loopback interface in this example
+: Mapping of SDP to CE
X: Physical interfaces used for realization of IETF network slice
S1: L0/L1/L2/L3 services used for realization of IETF network slice
T1: Tunnels used for realization of IETF network slice

Figure 20: CE-mode slice realization example between DU and CU-UP OPTION

The 3GPP Management System is expected to handle different IOCs for both DU and CU-UP. For each of those 3GPP network entities, one of the IOCs is the EP_RP, which describes each of the end-points in the association between 3GPP core entities, and the other IOC is the EP_Transport, which provides information attributes about the point of attachment of each 3GPP core entity to the transport network. Both objects are cross-referenced, so it is possible to get the information of one of them from the other.

Figure 21 shows the information provided at the DU side corresponding to the intended association with the CU-UP at the other end.

```
     +---------------------------------+
     |          EP_F1U CU-UP1          |<---+
     +---------------------------------+    |
     |   Parameter    |      Value     |    |
     +---------------------------------+    |
     |  localAddress  |     192.0.2.2  |    |
     +---------------------------------+    |
     | remoteipaddress|   198.51.100.2 |    |
     +---------------------------------+    |
     | epTransportRef |EP_Transport 100|    |
     +---------------------------------+    |
                     A                      |
                     |                      |
                     |                      |
                     V                      |
    +-----------------------------------+   |
    |         EP_Transport 100          |   |
    +-----------------------------------+   |
    |    Parameter     |      Value     |   |
    +-----------------------------------+   |
    |    ipAddress     |    192.0.2.1   |   |
    +-----------------------------------+   |
    |logicInterfaceType|      vlan      |   |
    +-----------------------------------+   |
    | logicInterfaceId |      100       |   |
    +-----------------------------------+   |
    |   NextHopInfo    |   192.0.2.254  |   |
    +-----------------------------------+   |
    |    qosProfile    |     5QI100     |   |
    +-----------------------------------+   |
    | epApplicationRef | EP_F1U CU-UP1  |<--+
    +-----------------------------------+
```

Figure 21: 3GPP IOCs at DU side for the DU1 CU-UP1 connection

Similarly, at CU-UP side the following objects are provided for setting up the network slice service towards DU, as represented in Figure 22.

```
     +-----------------------------------+
     |            EP_F1U DU1             |<---+
     +-----------------------------------+    |
     |   Parameter    |      Value       |    |
     +-----------------------------------+    |
     |  localAddress  |  198.51.100.2    |    |
     +-----------------------------------+    |
     | remoteipaddress|   192.0.2.2      |    |
     +-----------------------------------+    |
     | epTransportRef |EP_Transport 100|    |
     +-----------------------------------+    |
                     A                        |
                     |                        |
                     |                        |
                     V                        |
    +------------------------------------+    |
    |         EP_Transport 100           |    |
    +------------------------------------+    |
    |    Parameter     |      Value      |    |
    +------------------------------------+    |
    |    ipAddress     |  198.51.100.1   |    |
    +------------------------------------+    |
    |logicInterfaceType|      vlan       |    |
    +------------------------------------+    |
    | logicInterfaceId |      100        |    |
    +------------------------------------+    |
    |   NextHopInfo    | 198.51.100.254 |    |
    +------------------------------------+    |
    |    qosProfile    |     5QI100      |    |
    +------------------------------------+    |
    | epApplicationRef |   EP_F1U DU1    |<--+
    +------------------------------------+
```

Figure 22: 3GPP IOCs at CU-UP side for the DU1 CU-UP1 connection

This is the basic information from where deriving the set of parameters feeding the NSSM model as defined in [I-D.ietf-teas-ietf-network-slice-nbi-yang].

According to this example, the following mapping could be performed.

* SDPs: the SDPs in this example correspond to the IP addresses of the 3GPP core entities, thus 192.0.2.2 at the DU1 side and 198.51.100.2 at the CU-UP1 side, both contained in the EP_RP object.

* SLO / SLE policy: the SLO policy can be derived from the QoS profile indicated in the EP_Transport object. SLE information are not directly expressed in 3GPP IOCs, then, if needed, SLE information should be complemented by other means (e.g., the 3GPP Slice Profile could provide indication of high reliability which could be translated to SLE values in the NBI YANG model internally to the NSC).

* Peer SAP: the Next Hop info parameter in EP_Transport object can provide information about the SAP at the PE side, based on the IP address provided.

* AC: the conjugation of the IP address in the EP_Transport object, plus the information of the logical interface type and its identifier also in EP_Transport, can assist on determining the specific AC used for the network slice.

The resulting mapping is summarized in Figure 23.

```
        SDP1                                                  SDP2
     (192.0.2.2)                                    (198.51.100.2)
        o<----------------- IETF Network Slice ---------------->o
        +                                                       +
        +|<------------------------- S1 ---------------------->|+
        +|                                                     |+
        +|  EP_Transport                        EP_Transport  |+
        +|   (192.0.2.1)    |<------ T1 ---->|  (198.51.100.1) |+
        +|     /           v                v            \     |+
        +v    /       +-----+                +-----+      \    v+
     +--+--+ /        | PE1 |================| PE2 |        \ +-+---+
     |  +  |/ |       |     |                |     |     |   \| +   |
     |  o  X----------X     |                |     X----------X o   |
     |     |  |       |\    |                |    /|     |    |     |
     |     |  |       | \   |                |   / |     |    |     |
     |     |  |     Peer SAP|                | Peer SAP  |    |     |
     |     |  |(192.0.2.254)|================|(198.51.100.254)|     |
     |     |  |       |     |                |     |     |    |     |
     +-----+  |       +-----+                +-----+     |    +-----+
     Customer |       Provider               Provider    |    Customer
     Edge 1   |       Edge 1                 Edge 2      |    Edge 2
              |                                          |
        AC (vlan 100)                          AC (vlan 100)
```

Figure 23: CE-mode slice realization example between DU and CU-UP with values

Further parameters can be filled in the NS NBI YANG model from the information provided. For instance, since there is one single pair of EP_Transport objects, one on each end of the intended slice service, the connectivity construct can be requested as p2p. Since the ranges of IP address of both DU1 and CU-UP1 could pertain to different block of prefixes, the NSC can take the decision of realizing the network slice as a routed service. Here is important to remark that the IOCs from 3GPP do not provide any information regarding the mask applied to each prefix, so this can produce inconsistencies in the interpretation of the information received. Clearly this is a gap necessary to be solved.

In addition to that, the logical interface type and its identifier can be used as match criteria for mapping traffic between DU1 and CU-UP1 on the intended slice service.

As such, the NBI YANG model can result in something like:


```
{
  "data": {
    "ietf-network-slice-service:network-slice-services": {
      "slo-sle-templates": {
        "slo-sle-template": [
          {
            "id": "5QI100", /* QoS profile  as in EP_Transport*/
            "template-description": "5QI100 description"
          },
        ]
      },
      "slice-service": [
        {
          "service-id": "5GSliceMapping",
          "service-description": "example 5G Slice mapping",
          "slo-sle-template": "5QI100",
          "status": {
          },
          "sdps": {
            "sdp": [
              {
                "sdp-id": "01",
                "node-id": "DU1",
                "sdp-ip": "192.0.2.2",
                "service-match-criteria": {
                  "match-criterion": [
                    {
                      "index": 1,
                      "match-type": "vlan-match",
                      "target-connection-group-id": "DU-CU"
```

```
                      }
                    ]
                  },
                  "attachment-circuits": {
                    "attachment-circuit": [
                      {
                        "ac-id": "100",
                        "ac-ip-address": "192.0.2.1",
                        "ac-ip-prefix-length": ?,
                        "peer-sap-id": "192.0.2.254"
                      }
                    ]
                  },
                  "status": {
                  }
                },
                {
                  "sdp-id": "02",
                  "node-id": "CU-UP1",
                  "sdp-ip": "198.51.100.2",
                  "service-match-criteria": {
                    "match-criterion": [
                      {
                        "index": 1,
                        "match-type": "vlan-match",
                        "target-connection-group-id": "DU-CU",
                        "target-connectivity-construct-id": 1
                      }
                    ]
                  },
                  "attachment-circuits": {
                    "attachment-circuit": [
                      {
                        "ac-id": "100",
                        "ac-ip-address": "198.51.100.1",
                        "ac-ip-prefix-length": ?,
                        "peer-sap-id": "198.51.100.254"
                      },
                    ]
                  },
                  "status": {
                  }
                },
              ]
            },
            "connection-groups": {
              "connection-group": [
                {
```

```
                   "connection-group-id": "DU-CU",
                   "connectivity-type": "ietf-vpn-common:any-to-any",
                   "connectivity-construct": [
                     {
                       "cc-id": 1,
                       "a2a-sdp": [
                         {
                           "sdp-id": "01"
                         },
                         {
                           "sdp-id": "02"
                         },
                       ]
                     }
                   ]
                 }
               ]
             }
           }
         ]
       }
     }
   }
```


7.2. Example according to PE-mode (OPTION 2)

This example considers the request of a slice for realizing the F1-U [TS-38.470] interface between a DU and a CU-UP elements (i.e., INS4 in previous Figure 4). Note that the example is equally valid for the realization of any other case.

The example follows the PE-mode as described in Figure 24.

```
 +-----+        Association between X and Y              +-----+
 |     |    according to 3GPP (i.e., NgU/N3 interface)   |     |
 | gNB |<----------------------------------------------->| UPF |
 |     |                                                 |     |
 +-----+                                                 +-----+

 +-----+        Association between DU and CU-UP         +-----+
 |     |             (i.e., F1-U interface)              |     |
 |  DU |<----------------------------------------------->|CU-UP|
 |     |                                                 |     |
 +-----+                                                 +-----+
                    \__________  __________/
                                \/
              SDP1                                     SDP2
       (With PE1 parameters)                       (with PE2 parameters)
               o<--------- IETF Network Slice 1 ------->o
               +     |                            |     +
               +     |<----------- S1 ----------->|     +
               +     |                            |     +
               +     |    |<------ T1 ------>|    |     +
                 +   v    v                  v    v   +
                   + +----+                  +----+ +
    +-----+    |     | PE1|==================| PE2|          +-----+
    |     |    |     |    |                  |    |     |    |     |
    |     |----------X    |                  |    X----------|     |
    |     |    |     |    |                  |    |     |    |     |
    +-----+    |     |    |==================|    |     |    +-----+
               AC    +----+                  +----+     AC
    Customer         Provider                Provider        Customer
    Edge 1           Edge 1                  Edge 2           Edge 2


 Legend:
   O: Representation of the IETF network slice endpoints (SDP)
   +: Mapping of SDP to customer-facing ports on the PE
   X: Physical interfaces used for realization of IETF
 network slice service
   S1: L0/L1/L2/L3 services used for realization of IETF
 network slice service
   T1: Tunnels used for realization of IETF network slice service
```

Figure 24: PE-mode slice realization OPTION 2

The resulting mapping is summarized in Figure 25.

```
              SDP1                                     SDP2
       (With PE1 parameters)                       (with PE2 parameters)
          (192.0.2.254)                             (198.51.100.254)
               o<--------- IETF Network Slice 1 ------->o
               +     |                            |     +
               +     |<----------- S1 ----------->|     +
               +     |                            |     +
               +     |    |<------ T1 ------>|    |     +
                 +   v    v                  v    v   +
                   + +----+                  +----+ +
    +-----+    |     | PE1|==================| PE2|          +-----+
    |     |----------X    |                  |    |     |    |     |
    |     |    |     |    |                  |    X----------|     |
    |     |    |     |    |                  |    |     |    |     |
    +-----+    |     |    |==================|    |     |    +-----+
               |     +----+                  +----+     |
    Customer   |     Provider                Provider   |    Customer
    Edge 1     |     Edge 1                  Edge 2     |     Edge 2
               |                                        |
          AC (vlan 100)                            AC (vlan 100)
```

Figure 25: PE-mode slice realization OPTION 2

From NBI YANG: The IETF network slice controller (NSC) uses 'node-id' (PE device ID), 'attachment circuit' (ACs) to map SDPs to the customer-facing ports on the PEs

Gap: no info received in regards PE device ID. However we can retrieve the PE port IP address from NextHopInfo parameter, as sdp-ip


```
{
  "data": {
    "ietf-network-slice-service:network-slice-services": {
      "slo-sle-templates": {
        "slo-sle-template": [
          {
            "id": "5QI100", /* QoS profile  as in EP_Transport*/
            "template-description": "5QI100 description"
          },
        ]
      },
      "slice-service": [
        {
          "service-id": "5GSliceMapping-PE-mode",
          "service-description": "example 5G Slice mapping
following PE mode",
          "slo-sle-template": "5QI100", /* QoS profile  as
in EP_Transport*/
```

```
          "status": {
          },
          "sdps": {
            "sdp": [
              {
                "sdp-id": "01",
                "node-id": "PE1",
                "sdp-ip": "192.0.2.254", /* NextHopInfo IP
address in EP_Transport */
                "service-match-criteria": {
                  "match-criterion": [
                    {
                      "index": 1,
                      "match-type": "vlan-match", /*logicInterfaceType*/
                      "target-connection-group-id": "DU-CU"
                    }
                  ]
                },
                "attachment-circuits": {
                  "attachment-circuit": [
                    {
                      "ac-id": "100", /*logicInterfaceId*/
                      "ac-ip-address": "192.0.2.254", /* Next
HopInfo IP address in EP_Transport, redundant, can be removed */
                      "ac-ip-prefix-length": ?, /* not available */
                      "peer-sap-id": "192.0.2.254"
                    }
                  ]
                },
                "status": {
                }
              },
              {
                "sdp-id": "02",
                "node-id": "PE2",
                "sdp-ip": "198.51.100.254", /* NextHopInfo IP address
in EP_Transport */
                "service-match-criteria": {
                  "match-criterion": [
                    {
                      "index": 1,
                      "match-type": "vlan-match", /*logicInterfaceType*/
                      "target-connection-group-id": "DU-CU",
                      "target-connectivity-construct-id": 1
                    }
                  ]
                },
                "attachment-circuits": {
```

```
                  "attachment-circuit": [
                    {
                      "ac-id": "100", /*logicInterfaceId*/
                      "ac-ip-address": "198.51.100.254", /* NextHopInfo
IP address in EP_Transport, redundant, can be removed */
                      "ac-ip-prefix-length": ?, /* not available */
                      "peer-sap-id": "198.51.100.254"
                    },
                  ]
                },
                "status": {
                }
              },
            ]
          },
          "connection-groups": {
            "connection-group": [
              {
                "connection-group-id": "DU-CU",
                "connectivity-type": "ietf-vpn-common:any-to-any",
** Note: there is a hint from NRM on {{TS-28.541}} Clause 4.3.11, 4.3.13, 5.3.20 relation
sip between 3GPP elements on the logical link connection with attributes localAddress and
 remoteAddress. This information may be correlated with the connectivity and analyzed to
make a decision on the connectivity type.**
                "connectivity-construct": [
                  {
                    "cc-id": 1,
                    "a2a-sdp": [
                      {
                        "sdp-id": "01"
                      },
                      {
                        "sdp-id": "02"
                      },
                    ]
                  }
                ]
              }
            ]
          }
        }
      ]
    }
  }
}
```

7.3. Example According to PE-mode with Meeting Point Extension of ACaaS (OPTION 3)

This example is based on the Option 2 when SDP is located on the PE and utilizing the same approach for the data model of the Network Slice Service, but "attachment-circuits" section of the model is referring to the identifiers that are created using the data models specified in [I-D.draft-ietf-opsawg-teas-attachment-circuit]

This example following the overall conception in [ZSM-003] of confederated data model approach and SDO Data Model cross-referencing in order to get quicker Service and Slice provisioning in multiple domains under various SDO areas of focus, fueling closed-loop automation direction in the Management lifecycle of Slices and Services.

3GPP NRM Rel 18 LogicalInterfaceInfo (Section 6.3.35 of [TS-28.541]) represents 3GPP IOC with TN-related parameters of the 3GPP subsystem interpreted in this example (Option 3) as CE network configuration of current model and may be referenced as a ’peer-sap-id’ remote endpoint of the attachment circuit with parameters as ’nf-termination-ip’ and ’nf-termination-vlan’ (see more on SAPs at [RFC9408]; and parameters related to the physical connection and associated with Bearer Service "ietf-ac-svc:attachment-circuits:ietf-bearer-svc".

3GPP NRM ConnectionPointInfo (Section 6.3 of [TS-28.541]) represents 3GPP IOC with link to the external IETF data model [I-D.draft-ietf-opsawg-teas-attachment-circuit] in order to link the corresponding 3GPP subsystem Transport Network-related slice Meeting Point (Clause 6.3.18 of [TS-28.541], EP_Transport) to the IETF Network Slice attachment circuit.

As the [RFC9453] has flexibility of Network-Specific abstraction, a need for more attention to connectivity parameters was identified during collaboration activity in O-RAN Alliance Working Group 9 between the 3GPP SA5 representatives and IETF contributors.

[I-D.draft-ietf-opsawg-teas-attachment-circuit] is used jointly to the Network Slice Service YANG model to capture and reflect IETF PE connectivity to 3GPP subsystem parameters such as:

* Physical parameters of the bearer, captured in the "ietf-bearer-svc" YANG Module of [I-D.draft-ietf-opsawg-teas-attachment-circuit], contains the physical connectivity parameters that the link is utilizing, site location, (3GPP) device information, the IETF PE is connected to, and administrative operational parameters as status and activation time constraints.

* Location information, correlated with NRM [TS-28.623] in corresponding 3GPP element id in Clause A 2.2.2 IOC ManagedElement.locationName attribute.

* Logical connectivity parameters: e.g., VLAN, IPv4, and IPv6.

* Routing protocols

While 3GPP NRM Rel 17 (Section 6.3.18 of [TS-28.541]) EP_Transport Attribute "nextHopInfoList" from Clause 6.3.18.2 is associated with "ietf-network-slice-service:network-slice-services:slice-service:sdp:sdp-ip" value, in 3GPP NRM Rel 18 [TS-28.541] Clause 6.3.18 EP_Transport Attribute list no longer contains IP address of TN element, but a link to IETF meeting point with connectionPointId value of "ietf-ac-svc:attachment-circuits:ac:name".

Provisioning procedures of the 3GPP Elements are captured in [TS-28.531] where relationship between NRM leaf and IETF AC "ietf-ac-svc:attachment-circuits:ac:name" is depicted.

Note: Possible values of the attribute, specifying the type of the connection point identifier "connectionPointIdType" are VLAN, MPLS, Segment, IPv4, IPv6, and Attachment Circuit (AC). In current example Option 3 "Attachment Circuit (AC)" is used.

Figure 26 captures Transport-related parameters.

```
              SDP1                                     SDP2
       (With PE1 parameters)                       (with PE2 parameters)
          (192.0.2.254)                             (198.51.100.254)
               o<--------- IETF Network Slice 1 ------->o
               +     |                            |     +
               +     |<----------- S1 ----------->|     +
               +     |                            |     +
               +     |    |<------ T1 ------>|    |     +
                 +   v    v                  v    v   +
  (192.0.2.1)        + +----+                  +----+ +      (198.51.100.1)
    +-----+    |     | PE1|==================| PE2|          +------+
    |     |----------X    |                  |    |     |    |      |
    | DU1 |    |     |    |                  |    X----------|CU-UP1|
    |     |    |     |    |                  |    |     |    |      |
    +-----+    |     |    |==================|    |     |    +------+
               |     +----+                  +----+     |
    Customer   |     Provider                Provider   |    Customer
    Edge 1     |     Edge 1                  Edge 2     |     Edge 2
               |                                        |
          AC-ID (vlan 100)                          AC-ID (vlan 100)
```

Figure 26

The following attributes mapping is assumed in this example:

```
---DU1---
3GPP NRM {{TS-28.541}} Clause 6.3.18 EP_Transport
         ipAddress: '192.0.2.1/24'
         localLogicalInterfaceInfo: "DU1_LogicalInterfaceInfo"
         qosProfile: '5QI100'
         connectionPointRefList: "DU1_Meeting_point"
3GPP NRM Rel 18 {{TS-28.541}} Clause 6.3.35 LogicalInterfaceInfo: "DU1_LogicalInterfaceIn
fo"
         logicalInterfaceType: 'VLAN'
         logicalInterfaceId: '100'
         systemName: 'DU1'
         portName: 'XE'
         routingProtocol: 'Static'

** Note: LogicalInterfaceInfo.routingProtocol has Allowed values:  RIP, IGMP, OSPF, EGP,
EIGRP, BGP, IS-IS.**
** Identified gap: No Static or Direct_connect value is available.**

3GPP NRM {{TS-28.541}} Clause 6.3.41   ConnectionPointInfo: "DU1_Meeting_point"
         connectionPointId: 'ac01-DU1'
         connectionPointIdType: 'Attachment_Circuit'

** Note: connectionPointIdType has Allowed values: VLAN, MPLS, Segment, IPV4, IPV6, Attac
hment Circuit (AC) with multiplicity: 1

3GPP NRM {{TS-28.623}} Clause A 2.2.2 IOC ManagedElement
```

```
         id: ’DU1’
         locationName: ’Site1.AAA1.ZIP1’
** Note: The physical location (e.g., an address) of an 3GPP entity. It may contain no in
formation to support the case where the derivative of ManagedElement needs to represent a
 distributed multi-location NE."**

---CU-UP1---
3GPP NRM {{TS-28.541}} Clause 6.3.18 EP_Transport
         ipAddress: ’198.51.100.1/24’
         localLogicalInterfaceInfo: "CU-UP1_LogicalInterfaceInfo"
         qosProfile: ’5QI100’
         connectionPointRefList: "CU-UP1_Meeting_point"

3GPP NRM Rel 18 {{TS-28.541}} Clause 6.3.35 LogicalInterfaceInfo: "CU-UP1_LogicalInterfac
eInfo"
         logicalInterfaceType: ’VLAN’
         logicalInterfaceId: ’100’
         systemName: ’CU-UP1’
         portName: ’XE’
         routingProtocol: ’Static’

3GPP NRM {{TS-28.541}} Clause 6.3.41   ConnectionPointInfo: "CU-UP1_Meeting_point"
         connectionPointId: ’ac01-CU-UP1’
         connectionPointIdType: ’Attachment_Circuit’

3GPP NRM {{TS-28.623}} Clause A 2.2.2 IOC ManagedElement
         id: ’CU-UP1’
         locationName: ’Site1.AAA2.ZIP2’
----
```


```
{
  "data": {
    "ietf-network-slice-service:network-slice-services": {
      "slo-sle-templates": {
        "slo-sle-template": [
          {
            "id": "5QI100", /* QoS profile  as in EP_Transport*/
            "template-description": "5QI100 description"
          },
        ]
      },
      "slice-service": [
        {
          "service-id": "5GSliceMapping-PE-mode",
          "service-description": "example 5G Slice mapping
following PE mode",
          "slo-sle-template": "5QI100", /* QoS profile  as
in EP_Transport*/
          "status": "active"
          "sdps": {
            "sdp": [
              {
```

```
                "sdp-id": "01",
                "node-id": "PE1",
                "ac-svc-name:ac-ref": [
                 "ac01-DU1"
** 3GPP NRM {{TS-28.541}} DU1.ConnectionPointInfo."DU1_Meeting_point".connectionPointId *
*
                 ]
                "status": "active"
              {
                "sdp-id": "02",
                "node-id": "PE2",
                "ac-svc-name:ac-ref": [
                 "ac01-CU-UP1" **3GPP NRM {{TS-28.541}} CU-UP1.ConnectionPointInfo.
"CU-UP1_Meeting_point".connectionPointId**
                 ]
                "status": "active"
              },
              ]
              },
          },
          "connection-groups": {
            "connection-group": [
              {
                "connection-group-id": "DU-CU",
                "connectivity-type": "ietf-vpn-common:any-to-any",
                "connectivity-construct": [
                  {
                    "cc-id": 1,
                    "a2a-sdp": [
                      {
                        "sdp-id": "01"
                      },
                      {
                        "sdp-id": "02"
                      },
                    ]
                  }
                ]
              }
            ]
          }
        }
      ]
    }
  }

"ietf-ac-svc:attachment-circuits": {
       "ac": [
         {
```

```
           "name": "ac01-DU1",
** 3GPP NRM {{TS-28.541}} Clause 6.3.41   ConnectionPointInfo.connectionPointId **
           "description": "meeting point DU1-PE1",
           "l2-connection": {
             "encapsulation": {
               "type": "ietf-vpn-common:dot1q",
** 3GPP NRM Rel 18 {{TS-28.541}} Clause 6.3.35 LogicalInterfaceInfo.logicalInterfaceType
**
         logicalInterfaceType: ’VLAN’
               "dot1q": {
                 "cvlan-id": 100
** 3GPP NRM Rel 18 {{TS-28.541}} Clause 6.3.35 LogicalInterfaceInfo.logicalInterfaceId **
               }
             },
             "bearer-reference": "line-156"
           },
           "ip-connection": {
             "ipv4": {
               "local-address": "192.0.2.254",
               "prefix-length": 24,
               "address": [
                 {
                   "address-id": "1",
                   "customer-address": "192.0.2.1"
**3GPP NRM {{TS-28.541}} Clause 6.3.18 DU1.EP_Transport.ipAddress**
                 }
               ]
             },
           "routing-protocols": {
             "routing-protocol": [
               {
                 "id": "1",
                 "type": "ietf-vpn-common:direct-routing"
** 3GPP NRM Rel 18 {{TS-28.541}} Clause 6.3.35 LogicalInterfaceInfo.routingProtocol **
               }
             ]
           }
           "name": "ac01-CU-UP1",
** 3GPP NRM {{TS-28.541}} Clause 6.3.41   ConnectionPointInfo.connectionPointId **
           "description": "meeting point CU-UP1-PE2",
           "l2-connection": {
             "encapsulation": {
               "type": "ietf-vpn-common:dot1q",
** 3GPP NRM Rel 18 {{TS-28.541}} Clause 6.3.35 LogicalInterfaceInfo.logicalInterfaceType
**
               "dot1q": {
                 "cvlan-id": 100
** 3GPP NRM Rel 18 {{TS-28.541}} Clause 6.3.35 LogicalInterfaceInfo.logicalInterfaceId **
               }
             },
```

```
              "bearer-reference": "line-345"
            },
            "ip-connection": {
              "ipv4": {
                "local-address": "198.51.100.254",
                "prefix-length": 24,
                "address": [
                  {
                    "address-id": "1",
                    "customer-address": "198.51.100.1"
**3GPP NRM {{TS-28.541}} Clause 6.3.18 CU-UP1.EP_Transport.ipAddress**
                  }
                ]
              },
            "routing-protocols": {
              "routing-protocol": [
                {
                  "id": "1",
                  "type": "ietf-vpn-common:direct-routing"
** 3GPP NRM Rel 18 {{TS-28.541}} Clause 6.3.35 LogicalInterfaceInfo.routingProtocol **
                }
              ]
            }
          }

"ietf-ac-svc:ietf-bearer-svc":{
   "bearers": [
          {
            "id": "line-156" //Note that bearer-reference is returned in the response
            "description": "link DU1-PE1"
            "customer-point": {
              "identified-by": "ietf-bearer-svc:site-and-device-id",
                "device": {
                  "device-id": "DU1"
** Either 3GPP NRM Rel 18 {{TS-28.541}} Clause 6.3.35 LogicalInterfaceInfo: "DU1_LogicalI
nterfaceInfo".
systemName or 3GPP NRM {{TS-28.623}} Clause A 2.2.2 IOC ManagedElement.DU1.id **
                  "site": {
                    "site-id": "Site1.AAA1.ZIP1"
** 3GPP NRM {{TS-28.623}} Clause A 2.2.2 IOC ManagedElement.DU1.locationName**
            }
           }
          }
            "id": "line-345"
            "description": "link CU-UP1-PE2"
            "customer-point": {
              "identified-by": "ietf-bearer-svc:site-and-device-id",
              "device": {
                  "device-id": "CU-UP1"
```

```
** Either 3GPP NRM Rel 18 {{TS-28.541}} Clause 6.3.35 LogicalInterfaceInfo: "CU-UP1_Logic
alInterfaceInfo".
systemName or 3GPP NRM {{TS-28.623}} Clause A 2.2.2 IOC ManagedElement.CU-UP1.id **
                 "site": {
                   "site-id": "Site1.AAA2.ZIP2"
** 3GPP NRM {{TS-28.623}} Clause A 2.2.2 IOC ManagedElement.CU-UP1.locationName**
        }
       }
      }
     }
    }
  ]
 }
}
```

8. Gap Analysis

The way in which 3GPP is characterizing the slice endpoint (i.e., EP_Transport) is based on Layer 3 information (e.g., the IP Address). However the information provided seems not to be sufficient for instructing the IETF Network Slice Controller for the realization of the IETF NEtwork Slice. For instance, some basic information such as the mask associated to the IP address of the EP_Transport is not specified, as well as other kind of parameters like the connection MTU or the connectivity type (unicast, multicast, etc). More sophisticated information could be required as well, like the level of isolation or protection necessary for the intended slice.

In the case in which the 3GPP managed function runs on a purpose-specific network element, the IP address specified in the EP_Transport IOC serves as reference to identify the CE endpoint, assuming the endpoint of the CE has been configured with that IP address. With that information (together with the logical interface ID) should be sufficient for the IETF NSC to identify the counterpart endpoint at the PE side, and configuring it accordingly (e.g., with a compatible IP address) for setting up the slice end-to-end. Similarly, the next hop information in EP_Transport can help validate the end-to-end slice between PE endpoints.

In the case in which the 3GPP managed function is instantiated as a virtualized network function, the direct association between the IP address of EP_Transport and the actual endpoint mapped at the CE is not so clear. It could be the case, for instance when the virtualized network function is instantiated at the internal of a data center, that the CE facing the PE is far from the point where the function is deployed, being that connectivity extended through the internals of the data center (or by some internal configuration of a virtual switch in a server). In these situations additional information is needed for accomplishing the end-to-end connection.

At the same time, [TS-28.541] IOC contains useful parameters to be used in IETF Network Slice creation mechanism and enriching IETF Network Slice model. The following parameters may be suggested as a candidates to the correlation of the IETF Network Slice parameters and IETF Network Slice model enrichments:

* For the latency, dLThptPerSliceSubnet, uLThptPerSliceSubnet, reliability and delayTolerance attributes, the following NRM apply (with reference to the section in that specification):

  - CNSliceSubnetProfile (section 6.3.22 in [TS-28.541])

  - RANSliceSubnetProfile (section 6.3.23 in [TS-28.541])

  - TopSliceSubnetProfile (section 6.3.24 in [TS-28.541])

* For the qosProfile attribute, the NRM which applies is EP_Transport (detailed in section 6.3.18 in [TS-28.541])

9. IANA Considerations

This document makes no request of IANA.

Note to RFC Editor: this section may be removed on publication as an RFC.

10. Security Considerations

This document adheres to the security and privacy conisderations described in [RFC9543].

Specifically, the interaction between the 3GPP Management System and the IETF NSC should be secure to avoid attacks from maliciuos actors that could compromise the provision and operations of IETF Network Slice Services.

Apart from that, slice requests for different services should not be visible among them, especially in which concerns aspects such as SLO / SLE.

11. Evolution Considerations

3GPP NRM evolution of the data model approach is considered for Rel. 18.

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13. Annex 1: 3GPP Network Slice Mapping Parameters

The network slice concept was introduced in 3GPP specifications from the first 5G release, corresponding to Release 15. As captured in [TS-23.501], a network slice represents a logical network providing specific network capabilities and network characteristics.

To make slicing a reality, every technical domain is split into one or more logical network partitions, each referred to as a network slice subnet. The definition of multiple slice subnets on a single domain allows each segment to provide differentiated behaviors, in terms of functionality and/or performance, tailored to some specific needs. The stitching of slice subnets across the RAN, CN and TN results in the definition of 5G network slices in 3GPP.

From a management viewpoint, the concept of network slice subnet represents an independently manageable yet composable portion of a network slice. The rules for the definition of network slice subnet and their composition into network slices are detailed in the 5G Network Resource Model (NRM) [TS-28.541], specifically in the Network Slice NRM fragment. This fragment captures the information model of 5G network slicing, which specifies the relationships between different slicing related managed entities, which is represented as Information Object Class (IOC). The IOC that have been defined including: NetworkSlice IOC, NetworkSliceSubnet IOC, ManagedFunction IOC and EP_Transport IOC.

Information Object Class EP_Transport [TS-28.541] Clause 6.3.18 represents logical interface parameters of 3GPP subsystems, providing specific network capabilities and network characteristics. Relationships of Transport slicing-related 3GPP IOCs and IETF domain represented on the Figure X for NgU/N3 slices with traffic between 3GPP CU-UP (or ORAN) CU-UP and 3GPP UPF, while the Figure Y similarly represents F1-U slices with traffic between 3GPP (or ORAN) DU and 3GPP (or ORAN) CU-UP.

```
                +-----------------------------------+
                |      Slices in 3GPP domain        |
                |  Model defined in IOC TS-28.541   |
                |          NgU/N3 slices            |
                +----+-------------------------+--+
   +-----------------|+                         |
   |   3GPP CU-UP /  ||                       +-|---------------+
   | ORAN O-CU-UP #1 ||        .------.       | |3GPP (i)UPF #1 |
   | +---------------V|      ,'  TN   `.      +-V---------------+|
   | | EP_NgU link to |     |  domain   |     | EP_N3 link to  ||
   | |     UPF #1     |    ;             :    |    CU-UP #1    ||
   | |+---------------|    ;  .-------.  :    +----------------+||
   | ||EP_Transport 10+------(Slice 10 )------|EP_Transport 10|||
   | |+---------------|   |   `-------'   |   +----------------+||
   | |                |   |               |   |                 ||
   | |+---------------|   :   .-------.   ;   +-----------------||
   | ||EP_Transport 20+------(Slice 20 )------|EP_Transport 20 ||
   | |+---------------|A   :  `-------'  ;   A+-----------------||
   | +----------------||    |           |    |+----------------+|
   |            . . . ||     |         |     || . . .           |
   | +----------------||      `.     ,'      |+----------------+|
   | | EP_NgU link to ||        `---'        || EP_NgU link to ||
   | |     UPF #N     ||                     ||   CU-UP #N     ||
   | +----------------||                     |+----------------+|
   +------------------+|                     |+-----------------+
                       |                     |
                +------+---------------------+--------+
                |    logical transport interfaces     |
                |     e.g. GTP-U, IPSec endpoint      |
                +-------------------------------------+
```

Figure 27: Slicing example realization between 3GPP subsystems and TN on the NgU/N3 interface

```
                +-----------------------------------+
                |      Slices in 3GPP domain        |
                |  Model defined in IOC TS-28.541   |
                |            F1-U slices            |
                +-+------------------------+------+
   +--------------|+                       +|-----------------+
   |  3GPP DU /   ||                       ||  3GPP CU-UP /   |
   | ORAN O-DU #1 ||                       ||ORAN O-CU-UP #1  |
   |              ||         .-----.       ||                 |
   |+-------------V|       ,'  TN   '.     +V---------------+ |
   || EP_F1-U link |      |  domain   |    |EP_F1-U link to | |
   || to CU-UP #1  |    ;             :    |     DU #1      | |
   |+--------------|    ;   .-----.   :    +---------------+ | |
   ||EP_Transport 1+-------(Slice 1)-------|EP_Transport 1| | |
   |+--------------|   |    '-----'    |   +--------------+ | |
   ||              |   |               |   |                | |
   |+--------------|   :    .-----.    ;   +--------------+ | |
   ||EP_Transport 2+-------(Slice 2)-------|EP_Transport 2| | |
   |+--------------|A   :   '-----'   ;   A+--------------+ | |
   |+--------------||    |           |    |+----------------+ |
   |         . . . ||     |         |     || . . .            |
   |+--------------||      '.     ,'      |+----------------+ |
   || EP_F1-U link ||        '---'        ||EP_F1-U link to | |
   || to CU-UP #N  ||                     ||     DU #N      | |
   |+--------------||                     |+----------------+ |
   +---------------+|                     |+------------------+
                    |                     |
                    |                     |
             +------+---------------------+--------+
             |    logical transport interfaces     |
             |     e.g. GTP-U, IPSec endpoint      |
             +-------------------------------------+
```

Figure 28: Slicing example realization between 3GPP subsystems and TN on the F1-U interface

For the transport (i.e., connectivity) related part of a network slice, the key focus is on the EP_Transport IOC. Instances of this IOC serves to instantiate 3GPP interfaces (e.g., N3) which are needed to support Network Slicing and to define Network Slice transport resources within the 5G NRM. In a nutshell, the EP_Transport IOC permits to define additional logical interfaces for each slice instance of the 3GPP user plane.

According to [TS-28.541], the EP_Transport construct on 3GPP side has the following attributes: ipAddress, logicaInterfaceInfo, nextHopInfo, qosProfile and epApplicationRef In which, nextHopInfo could be used for choosing PE node in transport network and LogicalInterfaceInfo could be used for Transport Network Slice mapping.

nextHopInfo (optional): identifies the ingress transport node. Each node can be identified by any combination of IP address of next-hop router of transport network, system name, port name and IP management addresses of transport nodes.

logicInterfaceInfo (mandatory): a set of parameters, which includes logicInterfaceType and logicInterfaceId. It specifies the type and identifier of a logical interface. It could be a VLAN ID, MPLS Tag or Segment ID. This is assigned uniquely per slice.

From the Transport Network domain side, these parameters assist on the definition of the CE transport interface configuration and shall be taken as an input to the transport service model to create coherent Network Slice transport service. Figure 29 illustrates how the EP_Transport parameters can relate to the IETF ones for determining the endpoint connectivity.

```
+-----------------------+        .------.        +-----------------+
|     3GPP CU-UP /      |      ,'  TN   '.       | 3GPP (i)UPF #1  |
|    ORAN O-CU-UP #1    |     |  domain   |      |                 |
|+----------------------|  +-----------+   :    +----------------+|
||EP_NgU link to UPF #1 |  |   PE 1    |   :    | EP_N3 link to  ||
||                      |  |           |    :   |    CU-UP #1    ||
||+---------------------|  | .-------. |    |   +---------------+||
|||  EP_Transport for   +--+(Slice 10 )+----+---| EP_Transport  |||
|||     S-NSSAI FWA     |  |A'-------' |    ;   +---------------+||
|||logicInterfaceType = |  +|----------+   ;    +----------------+|
|||        Vlan ID      |   |:              ;    +-----------------+
||| logicInterfaceId =  |   | |           |
|||      Vlan 200       |   |  |         |
|||ipAddress = 192.0.2.1|   |   '.     ,'
||+--------------A------|   |     '---'
|+---------------|------| +-+-------------------+
+----------------|------+ |   nextHopInfoList   |
                 |        |NextHopInfo = IP/mask|
  +--------------+------+ |       of PE 1       |
  | epApplicationRef =  | | system name = PE 1  |
  |EP_NgU link to UPF#1 | |  port name = Gi1/1  |
  +---------------------+ +---------------------+
```

Figure 29: Example of 3GPP EP_Transport IOC TS-28.541 parameters with correlation to IETF

Furthermore, that same parameters should be leveraged for constituting the connectivity construct allowing endpoint interconnection. That is, there is no additional information that could be leveraged at service level that the one provided by EP_Transport, which essentially reflects an endpoint view. Figure 15 represents this relationship between 3GPP and IETF parameters.

```
  3GPP subsystem - CE                   Transport Network node - PE
+-----------------------+                +-----------------------+
|InformationObjectClass|                 |   IETF Slice Model    |
|                       <----------------->                       |
|     EP_Transport      |                 |  LxSM + extensions    |
+-----------------------+                +-----------------------+

Representation of connectivity:
EP_NgU/N3, link between (O)-CU-UP and UPF
F1-U, link between (O)-DU and (O)-CU-UP
```

Figure 30: Relationships of the 3GPP parameters with the IETF parameters

Leveraging on the EP_Transport information, the IETF NSC should be instructed through its NBI on performing the slice connection. Figure 31 graphically represents the slice connection (e.g., for Ng-U/N3) as expected by 3GPP by using connectivity constructs (of a IETF Network Slice service) to be configured by the IETF Network Slice Controller.

```
     Slices in 3GPP domain                         Slices in 3GPP domain
  Model defined in IOC TS-28.541          Model defined in IOC TS-28.541

+------------------+                                +------------------+
|3GPP CU-UP / ORAN |                                |   3GPP UPF #1    |
|   O-CU-UP #1     |      Slices in IETF domain     |                  |
|                  |                                |                  |
|+-----------------|     +----+           +----+    +-----------------+|
|| EP_NgU link to  |     |PE 1|           |PE 2|    |  EP_N3 link to  ||
||     UPF #1      |     |    |    .-.    |    |    |    CU-UP #1     ||
||+----------------|     |    |   |   |   |    |    +----------------+||
||| EP_Transport   |     |    |  |     |  |    |    |EP_Transport for|||
|||for S-NSSAI 100 o--------------PDU 1-------------o  S-NSSAI 100   |||
|||   Vlan 100     |     |    | |       | |    |    |    Vlan 100    |||
|||  IP 192.0.2.1  |<--->|    | ;       : |    |<-->|IP 198.51.100.1 |||
||+----------------|     |    |;         :|    |    +----------------+||
||+----------------|     |    ||         ||    |    +----------------+||
||| EP_Transport   |     |    ||         ||    |    |EP_Transport for|||
|||for S-NSSAI 200 o--------------PDU 2-------------o  S-NSSAI 200   |||
|||   Vlan 200     |     |    ||         ||    |    |    Vlan 200    |||
|||  IP 192.0.2.2  |<--->|    ||   TN    ||    |<-->|IP 198.51.100.2 |||
||+----------------|     |    ||         ||    |    +----------------+||
||                 |     |    ||         |+----+    +-----------------+|
|+-----------------|     |    ||         |          +------------------+
|+-----------------|     |    |:         ;+----+    +------------------+
|| EP_NgU link to  |     |    | :       ; |PE 3|    |   3GPP UPF #2    |
||     UPF #2      |     |    | |       | |    |    +-----------------+|
||Serving S-NSSAI  o--------------PDU 3-------------o  EP_N3 link to  ||
||      100        |<--->|    |  :     ;  |    |<-->|    CU-UP #1     ||
|+-----------------|     |    |  :     ;  |    |    | Serving S-NSSAI ||
+------------------+     +----+   `. ,'   +----+    |       100       ||
                                   ;                +-----------------+|
                                                    +------------------+
```

Figure 31: Example of CU-UP Slice in the 3GPP domain using an IETF Network Slice service

From the perspective of IETF Network Slice realization, some of these options could be realized in a straightforward manner while other could require of advanced features (e.g., PBR, SRv6, FlexE, etc). IETF Network Slice service may be a set of techniques and underlaying technologies, so multiple models may be used to define slice.

According to the [TS-28.541] attributes in the EP_Transport, the IETF Network Slice may be defined by the following combination of the parameters:

```
+------------------------------------------------------------------+
|                   EP_Transport attribute name                    |
|                                                                  |
+---------------+----------------+----------------+----------------+
|   ipAddress   |logicInterfaceId|   nextHopInfo  | qosProfile     |
+---------------+----------------+----------------+----------------+
|                   Different                     |  Same for all  |
|                   per slice                     |    slices      |
+---------------+---------------------------------+----------------+
|  Same for all |          Different              |  Same for all  |
|    slices     |          per slice              |    slices      |
+---------------+----------------+----------------+----------------+
|   Different   |  Same for all  |   Different    |  Same for all  |
|   per slice   |    slices      |   per slice    |    slices      |
+---------------+----------------+----------------+----------------+
|        Same for all            |   Different    |  Same for all  |
|          slices                |   per slice    |    slices      |
+--------------------------------+----------------+----------------+
|                            Different                             |
|                            per slice                             |
+---------------+--------------------------------------------------+
|  Same for all |                  Different                       |
|    slices     |                  per slice                       |
+---------------+--------------------------------------------------+
```

Figure 32: Variations of Slice implementation options

From the perspective of IETF Network Slice realization, some of these options could be realized in a straightforward manner while other could require of advanced features (e.g., PBR, SRv6, FlexE, etc).

IETF Network Slice service may be a set of techniques and underlaying technologies, so multiple models may be used to define slice.

14. Annex 2: Data Plane Mapping Options

The following picture shows the end-to-end network slice in data plane:

```
+--+       +-----+                           +----------------+
|UE|- - - -|(R)AN|---------------------------|       UPF      |
+--+       +-----+                           +----------------+
 |<----AN NS---->|<----------TN NS---------->|<----CN NS----->|
```

Figure 33: End-to-end network slice in data plane

The mapping between 3GPP slice and transport slice in user plane could happens in:

(R)AN: User data goes from (radio) access network to transport network

Editor’s Note: As figure 4.7.1. in [TS-28.530] describes, TN NS will not only exist between AN and CN but may also within AN NS and CN NS. However, here we just show the TN between AN and CN as an example to avoid unnecessary complexity.

The following picture shows the user plane protocol stack in end-to-end 5G system.

```
+-----------+                   |                  |               |
|Application+-------------------|------------------|---------------|
+-----------+                   |                  | +-----------+ |
| PDU Layer +-------------------|------------------|-| PDU Layer | |
+-----------+   +-------------+ |  +-------------+ | +-----------+ |
|           |   | ___Relay___ |--|--| ___Relay___ |-|-|           | |
|           |   |     \/ GTP-U|--|--|GTP-U\/ GTP-U|-|-|   GTP-U   | |
|   5G-AN   |   |5G-AN +------+ |  +------+------+ | +-----------+ |
|  Protocol |   |Protoc|UDP/IP|--|--|UDP/IP|UDP/IP|-|-|   UDP/IP  | |
|   Layers  |   |Layers+------+ |  +------+------+ | +-----------+ |
|           |   |      |  L2  |--|--|  L2  |  L2  |-|-|     L2    | |
|           |   |      +------+ |  +------+------+ | +-----------+ |
|           |   |      |  L1  |--|--|  L1  |  L1  |-|-|     L1    | |
+-----------+   +-------------+ |  +-------------+ | +-----------+ |
     UE              5G-AN      |        UPF       |      UPF      |
                                N3                 N9              N6
```

Figure 34: User plane protocol stack in end-to-end 5G system

The following figure shows the typical encapsulation in N3 interface.

```
+-----------------------+
| Application Protocols |
+-----------------------+
|       IP (User)       |
+-----------------------+
|          GTP          |
+-----------------------+
|          UDP          |
+-----------------------+
|          IP           |
+-----------------------+
|       Ethernet        |
+-----------------------+
```

Figure 35: Typical encapsulation in N3 interface

14.1. Layer 3 and Layer 2 Encapsulations

If the encapsulation above IP layer is not visible to Transport Network, it is not able to be used for network slice interworking with transport network. In this case, IP header and Ethernet header could be considered to provide information of network slice interworking from AN or CN to TN.

```
+------------------------+-----------
| Application Protocols  |      ^
+------------------------+      |
|       IP (User)        |  Invisible
+------------------------+     for
|          GTP           |     TN
+------------------------+      |
|          UDP           |      V
+------------------------+------------
|          IP            |
+------------------------+
|       Ethernet         |
+------------------------+
```

Figure 36: IP header for network slice interworking

The following field in IP header and Ethernet header could be considered:

IP Header:

* DSCP: It is traditionally used for the mapping of QoS identifier between AN/CN and TN network. Although some values (e.g. The unassigned code points) may be borrowed for the network slice interworking, it may cause confusion between QoS mapping and network slicing mapping.;

* Destination Address: It is possible to allocate different IP addresses for entities in different network slice, then the destination IP address could be used as the network slice interworking identifier. However, it brings additional requirement to IP address planning. In addition, in some cases some AN or CN network slices may use duplicated IP addresses.

* Option fields/headers: It requires that both AN and CN nodes can support the encapsulation and decapsulation of the options.

Ethernet header

* VLAN ID: It is widely used for the interconnection between AN/CN nodes and the edge nodes of transport network for the access to different VPNs. One possible problem is that the number of VLAN ID can be supported by AN nodes is typically limited, which effects the number of IETF network slices a AN node can attach to. Another problem is the total amount of VLAN ID (4K) may not provide a comparable space as the network slice identifiers of mobile networks. Two or more options described above may also be used together as the IETF Network Slice Interworking ID, while it would make the mapping relationship more complex to maintain.

In some other case, when AN or CN could support more layer 3 encapsulations, more options are available as follows:

If the AN or CN could support MPLS, the protocol stack could be as follows:

```
+------------------------+-----------
| Application Protocols  |      ^
+------------------------+      |
|       IP (User)        |  Invisible
+------------------------+     for
|          GTP           |     TN
+------------------------+      |
|          UDP           |      V
+------------------------+------------
|         MPLS           |
+------------------------+
|          IP            |
+------------------------+
|       Ethernet         |
+------------------------+
```

Figure 37: MPLS label for network slice interworking

A specified MPLS label could be used to as a IETF Network Slice Interworking ID.

If the AN or CN could support SRv6, the protocol stack is as follows:

```
      +------------------------+-----------
      | Application Protocols  |      ^
      +------------------------+      |
      |       IP (User)        |  Invisible
      +------------------------+     for
      |          GTP           |     TN
      +------------------------+      |
      |          UDP           |      V
      +------------------------+------------
      |          SRH           |
      +------------------------+
      |         IPv6           |
      +------------------------+
      |       Ethernet         |
      +------------------------+
```

Figure 38: SRH for network slice interworking

The following field could be considered to identify a network slice: SRH:

* SRv6 functions: AN/CN is supposed to support the new function extension of SRv6.

* Optional TLV: AN/CN is supposed to support the extension of optional TLV of SRH. ### Above Layer 3 Encapsulations If the encapsulation above IP layer is visible to Transport Network, it is able to be used to identify a network slice. In this case, UPD and GTP-U could be considered to provide information of network slice interworking between AN or CN and TN.

```
      +------------------------+----------
      | Application Protocols  |     |
      +------------------------+ Invisible
      |       IP (User)        |     for
      +------------------------+     TN
      |          GTP           |     |
      +------------------------+------------
      |          UDP           |
      +------------------------+
      |          IP            |
      +------------------------+
      |       Ethernet         |
      +------------------------+
```

Figure 39: UDP Header for network slice interworking

The following field in UDP header could be considered:

UDP Header:

* UDP Source port: The UDP source port is sometimes used for load balancing. Using it for network slice mapping would require to disable the load-balancing behavior.

A similar approach to this is followed in [I-D.ietf-dmm-tn-aware-mobility]

14.1.1. Consideration of the Virtual Network Functions (VNF)

In some 5G network slice deployments, it might be beneficial to deploy RAN and Core network functions such as DU, CU and UPF as virtual network functions (VNF) inside a data center (DC). As an example, consider Figure 40 where the CU and UPF have been deployed as VNF. The definition of the IETF network slice service INS1 stays identical to its PNF counterpart (physical network function) which are discussed in sections 7.2.1 to 7.2.5, i.e., INS1 is an IETF network slice service which provides the connectivity between SDP1 and SDP2 to satisfy certain SLO/SLE.

However, the mapping of INS1 might be different from previous use cases. Figure 40 shows one possible solution for mapping of INS1 where the 5G E2E network slice is first mapped inside the data center and then mapped to provider network PE nodes. One potential mapping in the data center is to use VxLAN ID to infer the identification of 5G E2E network slice inside the data center, and any of the options described in 7.2.1 to 7.2.5 in the provider network PE1 and PE2.

```
            <-------------------- INS1 ------------------->
              Mapping of INS1       Mapping of INS1
              in data center        in provider network
                      |              |
             SDP1     |              |                     SDP2
              |       |          .---|---.                  |
              V       V        ,’    |    ‘.                V
       |------------|        ,’      V      ‘.        |------------|
       |  --------  |     -------          -------    |  --------  |
       |  |   O...........+======================+..........O   |  |
       |  |      |  |     | PE1 |          | PE2 |    |  |      |  |
       |  | CU   |  |     |     |          |     |    |  | UPF  |  |
       |  --------  |     ------- Provider -------    |  -------   |
       |            |         ‘.  Network  ,’         |            |
       |------------|           ‘.       ,’           |------------|
            DC1                   -------                  DC2
       Legend:
            DC  Data Center
            O   SDP (N3 address)
            === Mapping of INS1 on Provider Network PE nodes
            ... Mapping of INS1 in data centers
```

Figure 40: VNF Consideration for IETF Network Slice Mapping

15. Summary

From all the options overviewed, it should be noted that current 3GPP Release 16 only supports through EP_Transport IOC the following slice handoff identifier: vlan tag. MPLS or SID labels. Thus, the consideration of more options as the ones here reported is a gap on 3GPP specifications.

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