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Considerations about Hierarchical IETF Network Slices

Abstract

Network slicing is targeted at existing or emerging customers or
services which may request for network connectivity services with a
specific set of Service Level Objectives (SLOs) and Service Level
Expectations (SLEs). In some network scenarios, there can be
requirements for the deployment of hierarchical network slices.The
general framework of IETF network slice supports hierarchical
network slicing, while the technologies for realizing hierarchical
IETF network slice need to be considered.

This document describes the typical scenarios of hierarchical IETF
network slices, and provides the considerations and requirements on
the technologies in different network planes to realize hierarchical
IETF network slices.

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1. **Introduction**

   Network slicing is targeted at existing or emerging customers or
   services which may request for network connectivity services with a
   specific set of Service Level Objectives (SLOs) and Service Level
   Expectations (SLEs). The concept and general framework of IETF
   network slice are described in [I-D.ietf-teas-ietf-network-slices].
   [I-D.ietf-teas-enhanced-vpn] describes the framework and
   technologies which can be used for IETF network slice realization by
   utilizing Virtual Private Network (VPN) and Traffic Engineering (TE)
   mechanisms with enhancements that specific services require over
   traditional VPNs.

   [I-D.ietf-teas-ietf-network-slices] mentions that IETF Network
   Slices may be combined hierarchically, which means that a network
   slice may itself be further sliced. The technologies for realizing
   hierarchical IETF network slice need to be considered.

This document describes the typical scenarios in which the deployment of hierarchical IETF network slices may be needed. This document also provides the considerations and requirements on the technologies in different network planes to realize hierarchical IETF network slices.

2. Scenarios of Hierarchical IETF Network Slices

In this section, several possible network scenarios of hierarchical IETF network slicing are introduced.

2.1. Per-Customer Network Slices in an Industrial Network Slice

One of the typical network slice deployment is in the multi-industrial network case, in which a physical network is used to deliver services of multiple vertical industries. Separate IETF network slices are provided for different industries, such as health-care, education, manufacturing, governmental affairs, etc. Then within the network slice of a specific industry, there may be need to create separate network slices for some or all of the customers within this industry.

For example, within the education network slice, some of the universities may require for a separate network slice to connect with a set of the branch campuses. Another examples is within the health-care network slice, some of the hospitals may require for a separate network slice for the connectivity and services between a set of the branch hospitals.
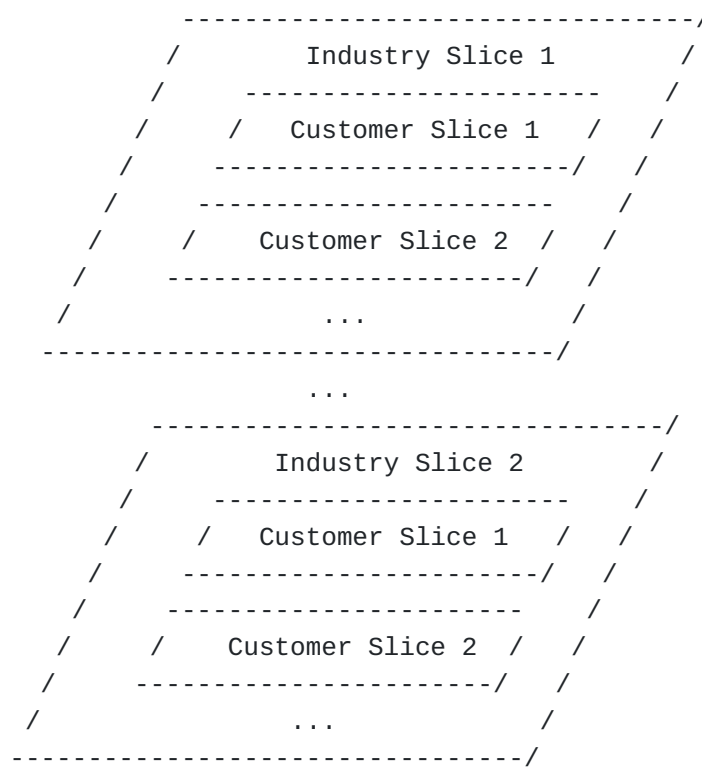
```
                 --------------------------------/
               /          Industry Slice 1          /
              /      ----------------------       /
             /      /    Customer Slice 1   /    /
            /      ----------------------/     /
           /      ----------------------      /
          /      /    Customer Slice 2   /    /
         /      ----------------------/     /
        /                ...                 /
     --------------------------------/
                       ...
              --------------------------------/
            /          Industry Slice 2          /
           /      ----------------------       /
          /      /    Customer Slice 1   /    /
         /      ----------------------/     /
        /      ----------------------      /
       /      /    Customer Slice 2   /    /
      /      ----------------------/     /
     /                ...                 /
  --------------------------------/
         Figure 1. Hierarchical Network Slices: Scenario 1
```

2.2. Per-application Network Slices in a Customer Network Slice

Another network slice deployment case is to provide dedicated IETF
network slices for some important customers as the first-level
network slices. While the customers may require to further split
their network slices into different sub-network slices for different
applications.

For example, a network slice for a hospital may be further divided
to carry different type of medical services, such as remote patient
monitoring, remote ultrasound diagnose, medical image transmission
etc.

```
                 --------------------------------/
               /          Customer Slice 1        /
             /       ----------------------      /
           /       /      APP Slice 1      /    /
         /       ----------------------/    /
       /       ----------------------      /
     /       /      APP Slice 2      /    /
   /       ----------------------/    /
 /                   ...              /
--------------------------------/
                    ...
                 --------------------------------/
               /          Customer Slice 2        /
             /       ----------------------      /
           /       /      APP Slice 1      /    /
         /       ----------------------/    /
       /       ----------------------      /
     /       /      APP Slice 2      /    /
   /       ----------------------/    /
 /                   ...              /
--------------------------------/
```
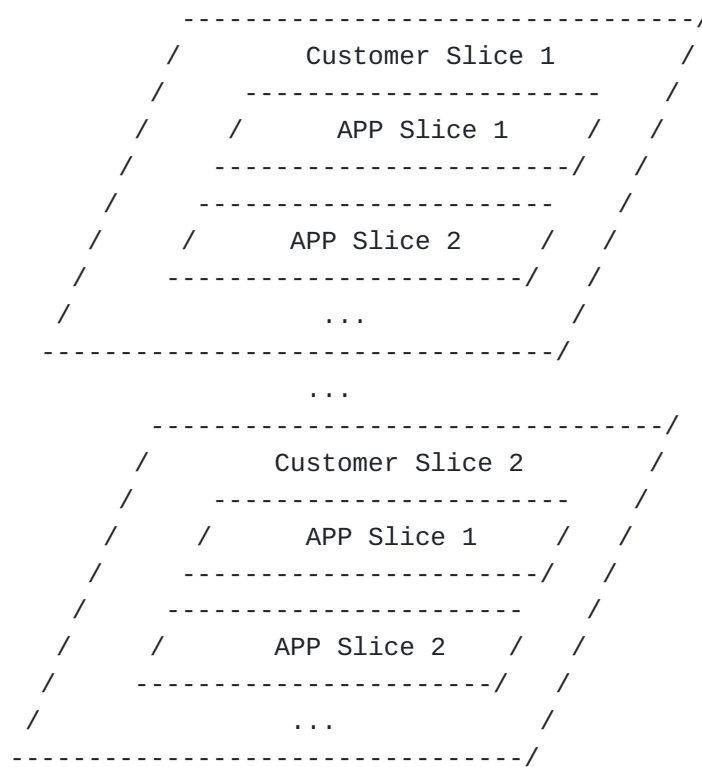
Figure 2. Hierarchical Network Slices: Scenario 2

2.3. Network Slice Services in a Wholesale Network Slice

IETF network slice can also be delivered as a wholesale service to
other network operators. In this case a network operator can be the
customer of a network slice, and it may also need to deliver IETF
network slice services to its customers. This is similar to the
Carrier's Carrier VPN service mode, while some additional
requirements on the SLOs and SLEs may be required by the second-
level network slice customer.

```
                  --------------------------------/
                 /         Wholesale Slice 1        /
                /     ----------------------      /
               /     /   Customer Slice 1  /    /
              /     ----------------------/   /
             /     ----------------------     /
            /     /   Customer Slice 2   /   /
           /     ----------------------/   /
          /                 ...            /
         --------------------------------/
                        ...
              --------------------------------/
             /         Wholesale Slice 2        /
            /     ----------------------      /
           /     /   Customer Slice 1  /    /
          /     ----------------------/   /
         /     ----------------------     /
        /     /   Customer Slice 2   /   /
       /     ----------------------/   /
      /                 ...            /
     --------------------------------/
```
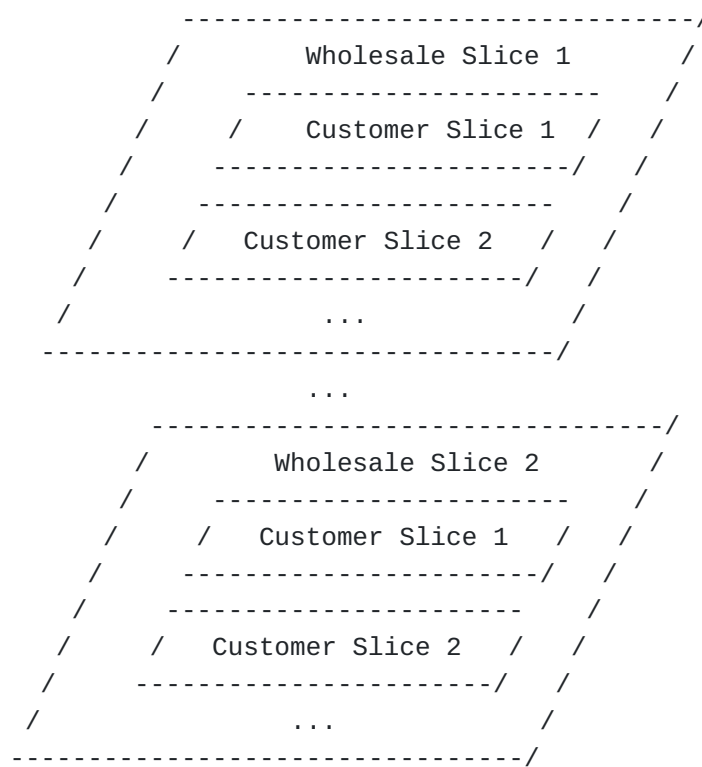
            Figure 3. Hierarchical Network Slices: Scenario 3

3. Considerations about Hierarchical Network Slice Realization

   To support the realization of hierarchical network slices, there
   will be specific requirements on the technologies used in each
   network plane. In this section, the requirements of hierarchical
   network slicing on the forwarding plane network resource
   partitioning, the data plane encapsulations, the control plane
   protocols and the management plane are analyzed.

3.1. Forwarding Plane Network Resource Partitioning

   For the realization of IETF network slices, the network resources in
   the underlying forwarding plane needs to be partitioned into
   different network resource partitions (NRPs), each NRP is used as
   the underlay network construct to support one or a group of IETF
   network slice services. In order to support hierarchical network
   slices, the forwarding plane network resources needs to be able to
   be partitioned in a hierarchical manner. Taking a two-level
   hierarchical network slice as an example, the bandwidth resource of
   a physical interface needs to be partitioned in two levels. There
   can be different options in modeling the interface resources of
   network resource partition.

   The first option is to treat the network resources in the first-
   level NRPs as a set of layer-3 sub-interfaces, each with dedicated
   link bandwidth, and the second-level NRPs are represented as virtual

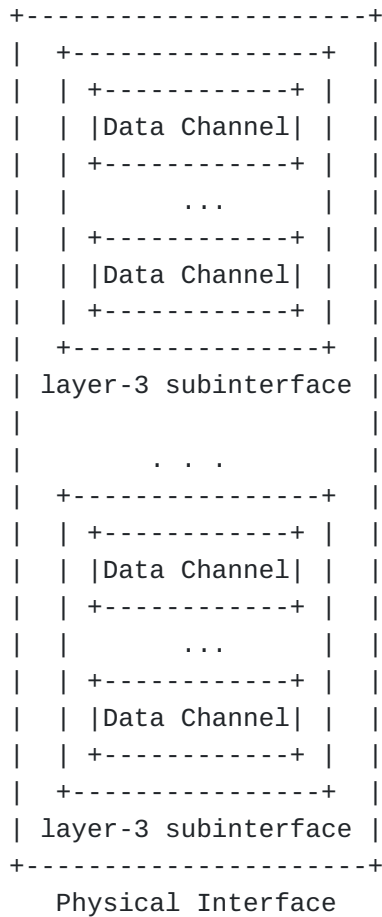data channels under the layer-3 sub-interfaces, as shown in the
figure below:

```
+----------------------+
|   +----------------+  |
|   | +------------+ |  |
|   | |Data Channel| |  |
|   | +------------+ |  |
|   |      ...       |  |
|   | +------------+ |  |
|   | |Data Channel| |  |
|   | +------------+ |  |
|   +----------------+  |
| layer-3 subinterface |
|                      |
|        . . .         |
|   +----------------+  |
|   | +------------+ |  |
|   | |Data Channel| |  |
|   | +------------+ |  |
|   |      ...       |  |
|   | +------------+ |  |
|   | |Data Channel| |  |
|   | +------------+ |  |
|   +----------------+  |
| layer-3 subinterface |
+----------------------+
     Physical Interface
```

Figure 4. Modeling of Network Resource Partition on Interface: Option 1

The second option is to treat the first-level NRPs as layer-2 sub-
interface of the layer-3 interface, and the second-level NRPs are
represented as virtual data channels under the layer-2 sub-
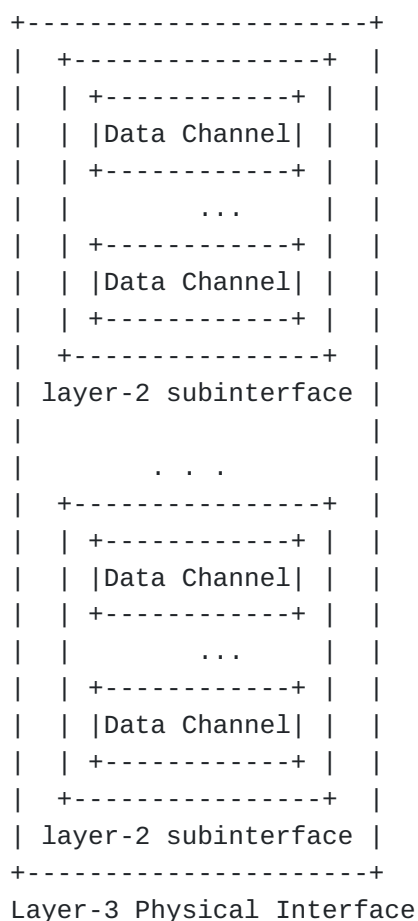interface, as shown in the figure below:

```
+---------------------+
|  +---------------+  |
|  | +-----------+ |  |
|  | |Data Channel| |  |
|  | +-----------+ |  |
|  |      ...      |  |
|  | +-----------+ |  |
|  | |Data Channel| |  |
|  | +-----------+ |  |
|  +---------------+  |
| layer-2 subinterface |
|                     |
|        . . .        |
|  +---------------+  |
|  | +-----------+ |  |
|  | |Data Channel| |  |
|  | +-----------+ |  |
|  |      ...      |  |
|  | +-----------+ |  |
|  | |Data Channel| |  |
|  | +-----------+ |  |
|  +---------------+  |
| layer-2 subinterface |
+---------------------+
 Layer-3 Physical Interface
```

Figure 5. Modeling of Network Resource Partition on Interface, Option 2

The options of the network resource partition modeling may have
different impact to the control plane in terms of the number of
control protocol sessions to be maintained, and the amount and types
of information to be distributed in the control plane. Depends on
the network deployment requirements, different resource partition
modeling options may be used.

3.2. Data Plane Identifiers

Traffic of IETF network slices can be steered into the corresponding
underlay network construct based on one or multiple fields in the
data packet, so that the corresponding NRPs are used for processing
and forwarding the packet. On the edge nodes of an IETF network
slice, traffic flows can be classified and mapped to IETF network
slices using flexible matching rules based on operators' local
policy. While on the intermediate network nodes, a dedicated data
plane NRP Identifier [I-D.dong-teas-nrp-scalability] can facilitate
the identification of the NRP and the set of network resources
allocated on the network nodes for packet processing.

For hierarchical IETF network slices, such data plane identifiers
may need to be able to identify both the first-level NRP and the
second-level NRP. There are several options in the design of the
data plane NRP identifier for hierarchical network slices.

The first option is to use a unified data plane identifier for both
the first-level NRP and the second-level NRP. In this case, the
first-level NRPs and the second-level NRPs are identified using
distinct identifier values.

```
+-----------------------------------------+
|    Unified NRP ID for different levels   |
+-----------------------------------------+
```
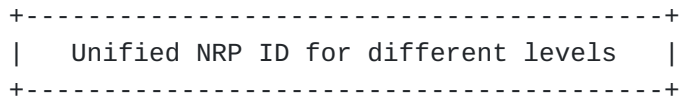
Figure 6. Unified NRP ID

The second option is to use a hierarchical identifiers for the
first-level NRP and the second-level NRP. In this case, the first
part of the identifier is used to identify the first-level NRP, and
the second part of the identifier is used to identify the second-
level NRP. Depends on the data plane technologies used, the
hierarchical NRP may be encapsulated in a continuous field in the
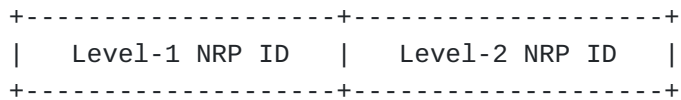packet, or may be positioned in separate fields.

```
+-------------------+-------------------+
|    Level-1 NRP ID   |    Level-2 NRP ID   |
+-------------------+-------------------+
```

Figure 7. Hierarchical NRP IDs

3.3. Control Plane

The control plane may be used for the distribution of the attributes
and states of the hierarchical NRPs and the associated data plane
identifiers among network nodes in the NRP and also to the network
controller. With different NRP modeling, the information may be
advertised as either layer-3 or layer-2 network information, which
may have different scalability implications to the control plane.
And as the number of hierarchical network slices increases, some
control plane optimization mechanisms may be needed to adopt to the
amount of information advertised.

3.4. Management Plane

For the management hierarchical network slices, the management
system of network operator needs to provide life-cycle management to
both the first-level network slices and the second-level network
slices. It should allow to manage the first-level and second-level
network slices separately, while the relationship between the first-
level and second-level network slices also need to be maintained in

the management system. The management system may need to support
additional functions and procedures for the management of
hierarchical network slices. Further analysis about the requirement
on the management plane is for further study.

4. Security Considerations

TBD

5. IANA Considerations

This document makes no request of IANA.

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7. Acknowledgments

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