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**Scalability Considerations for Network Resource Partition**

**draft-dong-teas-nrp-scalability-00**

Abstract

IETF network slice service aims to meet the connectivity demands of a

network slice customer with specific Service Level Objectives (SLOs)

and Service Level Expectations (SLEs) over a common underlay network.

A Network Resource Partition is a set of network resources that are

allocated from the underlay network to carry a specific set of

network traffic and meet the required SLOs and SLEs. One or multiple

IETF network slice services can be mapped to one network resource

partition.

As the demand for IETF network slice services increases,

scalability would become an important factor for the large scale

deployment of IETF network slices. Although the scalability of IETF

network slices can be improved by mapping a group of IETF network

slices to one network resource partition, there are concerns about

the scalability of network resource partitions. This document

describes the scalability considerations about network resource

partition in the network control plane and data plane, and some

optimization mechanisms are proposed.

Status of This Memo

This Internet-Draft is submitted in full conformance with the

provisions of [BCP 78](https://datatracker.ietf.org/doc/html/bcp78) and [BCP 79](https://datatracker.ietf.org/doc/html/bcp79).

Dong, et al. Expires 20 June 2022 [Page 1]

Internet-Draft NRP Scalability Considerations December 2021

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Table of Contents

[1](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-1). Introduction . . . . . . . . . . . . . . . . . . . . . . . . [3](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-3)

[2](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-2). Network Resource Partition Scalability Requirements . . . . . [4](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-4)

[3](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3). Network Resource Partition Scalability Considerations . . . . [5](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-5)

[3.1](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3.1). Control Plane Scalability . . . . . . . . . . . . . . . . [6](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-6)

[3.1.1](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3.1.1). Distributed Control Plane . . . . . . . . . . . . . . [6](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-6)

[3.1.2](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3.1.2). Centralized Control Plane . . . . . . . . . . . . . . [7](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-7)

[3.2](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3.2). Data Plane Scalability . . . . . . . . . . . . . . . . . [7](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-7)

[3.3](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3.3). Gap Analysis of Existing Mechanisms . . . . . . . . . . . [8](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-8)

[4](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-4). Proposed Scalability Optimizations . . . . . . . . . . . . . [9](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-9)

[4.1](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-4.1). Control Plane Optimizations . . . . . . . . . . . . . . . [9](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-9)

[4.2](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-4.2). Data Plane Optimizations . . . . . . . . . . . . . . . . [11](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-11)

[5](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-5). Solution Evolution for Improved Scalability . . . . . . . . . [12](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-12)

[6](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-6). Security Considerations . . . . . . . . . . . . . . . . . . . [13](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-13)

[7](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-7). IANA Considerations . . . . . . . . . . . . . . . . . . . . . [13](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-13)

[8](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-8). Contributors . . . . . . . . . . . . . . . . . . . . . . . . [13](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-13)

[9](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-9). Acknowledgments . . . . . . . . . . . . . . . . . . . . . . . [14](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-14)

[10](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-10). References . . . . . . . . . . . . . . . . . . . . . . . . . [14](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-14)

[10.1](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-10.1). Normative References . . . . . . . . . . . . . . . . . . [14](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-14)

[10.2](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-10.2). Informative References . . . . . . . . . . . . . . . . . [14](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-14)

Authors' Addresses . . . . . . . . . . . . . . . . . . . . . . . [16](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#page-16)

Dong, et al. Expires 20 June 2022 [Page 2]

Internet-Draft NRP Scalability Considerations December 2021

[**1**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-1)**. Introduction**

IETF Network Slice service aims to meet the connectivity demands of a

network slice customer with specific Service Level Objectives (SLOs)

and Service Level Expectations (SLEs) over a common underlay network.

[[I-D.ietf-teas-ietf-network-slices](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#ref-I-D.ietf-teas-ietf-network-slices)] defines the terminologies and the

characteristics of IETF network slices. It also discusses the

general framework, the components and interfaces for requesting and

operating IETF network slices. For the realization of IETF network

slice services, a concept called network resource partition is

introduced, which refers to a set of network resources that are

available in the underlay network to ensure the requested network slice

SLOs and SLEs can be met.

[I-D.ietf-teas-enhanced-vpn] describes the layered framework and

candidate technologies for delivering enhanced VPN (VPN+) services.

Enhanced VPN (VPN+) aims to meet the needs of some customers or

applications, including the applications that are associated with 5G,

which requires connectivity services with advanced characteristics,

such as the assurance of Service Level Objectives (SLOs) and specific

Service Level Expectations (SLEs). To meet the requirement VPN+

services, Virtual Transport Networks (VTNs) need to be created, each

of which has a subset of network resources allocated from the

physical underlay network and is associated with a logical network

topology. VPN+ services can be delivered by mapping one or a group

of overlay VPNs to the appropriate VTNs as the virtual underlay. The

VPN+ framework and technologies could be used for the realization of

IETF network slice services. In the context of IETF network slice,

the network resource partition refers to the resource attributes of a

VTN.

As the demand for IETF network slice services increases,

scalability would become an important factor for the large scale

deployment of IETF network slices. Although the scalability of IETF

network slices can be improved by mapping a group of IETF network

slices to one network resource partition, there are concerns about

the scalability of network resource partitions. This document

describes the scalability considerations about network resource

partition in the network control plane and data plane, and some

optimization mechanisms are proposed.

Dong, et al. Expires 20 June 2022 [Page 3]

Internet-Draft NRP Scalability Considerations December 2021

[**2**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-2)**. Network Resource Partition Scalability Requirements**

As described in [[I-D.ietf-teas-ietf-network-slices](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#ref-I-D.ietf-teas-ietf-network-slices)], IETF Network

Slices may be grouped together according to characteristics

(including SLOs and SLEs). This grouping allows an operator to host

a number of slices on a particular set of resources to reduce the

amount of state information needed in the network. This can help to

avoid the maintenance of per IETF network slice state in the underlay

network. The amount of network resource partitions needed in the

network depends on the scenarios of IETF network slices.

With the development and evolution of 5G and other services, it is

expected that an increasing number of IETF network slices will be

deployed. The number of network slices required depends on how IETF

network slices will be used, and the progress of network slicing for

the vertical industrial services. The potential number of IETF

network slice services and network resource partitions is analyzed by

classifying the network slice deployment into three typical

scenarios:

1. IETF network slices can be used by a network operator for

different types of services. For example, in a converged multi-

service network, different IETF network slices can be created to

carry mobile transport service, fixed broadband service and

enterprise services respectively, each type of service could be

managed by a separate department or management team. Some

service types, such as multicast service may also be deployed in

a dedicated network slice. In this case, a separate network

resource partition may need to be created for each service type.

It is also possible that a network infrastructure operator

provides IETF network slices to other network operators as a

wholesale service, and a network resource partition may also be

needed for each wholesale service customer. In this scenario,

the number of network resource partitions in a network could be

relatively small, such as in the order of 10 or so. This could

be one of the typical cases in the beginning of IETF network

slice deployment.

2. IETF network slices can be requested by customers in vertical

industries, where the assurance of SLOs and the fulfilment of

SLEs are quite important. At the early stage of the vertical

industrial services, a few top customers in some industries will

begin to use IETF network slices to provide performance assurance

to their business, such as smart grid, manufacturing, public

safety, on-line gaming, etc. The realization of such IETF

network slices typically requires to provide different network

resource partitions for different industries, and some top

customers can require dedicated network resource partitions for

Dong, et al. Expires 20 June 2022 [Page 4]

Internet-Draft NRP Scalability Considerations December 2021

strict service performance guarantee. Considering the number of

vertical industries, and the number of top customers in each

industry, the number of network resource partitions needed may be

in the order of 100.

3. With the evolution of 5G and cloud networks, IETF network slices

could be widely used by various vertical industrial customers and

enterprise customers who require guaranteed or predictable

service performance. The total amount of IETF network slices may

increase to thousands or more, although it is expected that the

number of IETF network slices would still be less than the number

of traditional VPN services in the network. Accordingly, the

number of network resource partitions needed may be in the order

of 1000.

As defined by 3GPP [[TS23501](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#ref-TS23501)], a 5G network slice is identified using

the Single Network Slice Selection Assistance Information (S-NSSAI),

which is a 32-bit identifier comprised of 8-bit Slice/Service Type

(SST) and 24-bit Slice Differentiator (SD). This allows the mobile

networks (the RAN and mobile core networks) to support a large number

of 5G network slices. Although it is likely that multiple 5G network

slices are mapped to the same IETF network slice, in some cases the

number of IETF network slices may be comparable to the number of 5G

network slices, and the required network resource partitions may

increase as well.

8-bit 24-bit

+------------+-------------------------+

| SST | Slice Differentiator |

+------------+-------------------------+

Figure 1. Format of S-NSSAI in 3GPP

Thus realization of IETF network slices needs to meet the scalability

requirement of IETF network slice services in different scenarios.

The increased number of IETF network slice services will introduce

additional complexity and overhead both to the control plane and the

data plane, especially in the aspects related to the underlay network

resource partitions. Although in many cases multiple IETF network

slice services can be mapped to the same network resource partition,

there still can be scalability challenges with the increased number

of network resource partitions.

[**3**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3)**. Network Resource Partition Scalability Considerations**

In this section, the scalability of Network Resource Partition in the

control plane and data plane is analyzed to understand the possible

gaps in meeting the scalability requirement of IETF Network Slices.

Dong, et al. Expires 20 June 2022 [Page 5]

Internet-Draft NRP Scalability Considerations December 2021

[**3.1**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3.1)**. Control Plane Scalability**

The control plane of network resource partition could be based on the

hybrid of a centralized controller and the distributed control plane.

[**3.1.1**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3.1.1)**. Distributed Control Plane**

For the delivery of IETF network slice services, it is necessary to

create multiple network resource partitions, each can be associated

with a customized logical topology. The network resource attributes

and the associated logical topology information of each network

resource partition may need to be exchanged among the network nodes.

The scalability of the distributed control plane used for the

distribution of network resource partition information needs to be

considered in the following aspects:

\* The number of control protocol instances maintained on each node

\* The number of protocol sessions maintained on each link

\* The number of routes advertised by each node

\* The amount of attributes associated with each route

\* The number of route computation (i.e. SPF computation) executed

by each node

As the number of network resource partitions increases, it is

expected that in some of the above aspects, the overhead in the

control plane may increase dramatically. For example, the overhead

of maintaining separated control protocol instances (e.g. IGP

instances) for different network resource partitions is considered

higher than maintaining the information of separated network resource

partitions in the same control protocol instance with appropriate

separation, and the overhead of maintaining separate protocol

sessions for different network resource partitions is considered

higher than using a shared protocol session for the information

exchange of multiple network resource partitions. To meet the

requirement of the increasing number of network resource partitions,

It is suggested to choose the control plane mechanisms which could

improve the scalability while still provide the required

functionality.

Dong, et al. Expires 20 June 2022 [Page 6]

Internet-Draft NRP Scalability Considerations December 2021

[**3.1.2**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3.1.2)**. Centralized Control Plane**

By introducing the centralized network controller, the SDN approach

can reduce the amount of control plane overhead in the distributed

control plane, while it may also transfer some of the scalability

concerns from network nodes to the centralized controller, thus the

scalability of the controller also needs to be considered.

To provide global optimization for the Traffic Engineered (TE) paths

in different network resource partitions, the controller needs to

keep the topology and resource information of all the network

resource partitions up-to-date. To achieve this, the controller may

need to maintain a communication channel with each network node in

the network. When there is significant change in the network, or

multiple network resource partitions requires global optimization

concurrently, there may be a heavy processing burden at the

controller, and a heavy load in the network surrounding the

controller for the distribution of the updated network state and the

TE paths.

[**3.2**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3.2)**. Data Plane Scalability**

To provide different IETF network slice services with the required

SLOs and SLEs, it is necessary to allocate different subsets of

network resources as different network resource partitions to avoid

or reduce the unexpected interruption. As the number of network

resource partitions increases, it is required that the underlying

network can provide fine-granular network resource partitioning,

which means the amount of state about the partitioned network

resources to be maintained on the network nodes will also increase.

In packet forwarding, IETF network slice service traffic needs to be

processed according to the topology and resource attributes of the

network resource partition it is mapped to, this means that some fields

in the data packet needs to be used to identify the network resource

partition and its associated topology either directly or implicitly.

Different approaches of encapsulating the network resource partition

information in data packet can have different scalability

implications.

One practical approach is to reuse some of the existing fields in the

data packet to additionally identify the network resource partition

the packet belongs to. For example, the destination IP addresses or

the MPLS forwarding labels may be reused to further identify the

network resource partition. This can avoid the cost of introducing

new fields in the data packet, while since it introduces additional

semantics to the existing fields, the processing of the existing

fields in packet forwarding may need to be changed. Moreover,

Dong, et al. Expires 20 June 2022 [Page 7]

Internet-Draft NRP Scalability Considerations December 2021

introducing resource semantics to existing identifiers in the packet

(e.g. IP addresses, MPLS forwarding labels, etc.) may result in the

increase of the amount of the existing IDs in proportion to the

number of the network resource partitions, which may cause

scalability problem in networks where a relatively large number of

network resource partitions is needed.

An alternative approach is to introduce a new dedicated field in the

data packet for identifying the network resource partition. This

could avoid the impacts to the existing fields in the packet. And if

this new field carries a global-significant network resource

partition identifier, it could be used together with the existing

fields to determine the packet forwarding behavior. The potential

issue with this approach is the difficulty in introducing a new field

in some of the data plane technologies.

In addition, the introduction of network resource partition specific

packet forwarding has impact on the scalability of the forwarding

entries on network nodes, as a network node may need to maintain

separate forwarding entries for each network resource partition it

participates in.

[**3.3**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-3.3)**. Gap Analysis of Existing Mechanisms**

One candidate mechanism to build network resource partition is to use

resource aware Segment Identifiers (either SR-MPLS or SRv6) in the

data plane as described in [[I-D.ietf-spring-resource-aware-segments](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#ref-I-D.ietf-spring-resource-aware-segments)]

[[I-D.ietf-spring-sr-for-enhanced-vpn](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#ref-I-D.ietf-spring-sr-for-enhanced-vpn)], and distribute the resource

attribute and the associated logical topology of each network

resource partition based on either Multi-topology

[[I-D.ietf-lsr-isis-sr-vtn-mt](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#ref-I-D.ietf-lsr-isis-sr-vtn-mt)], Flex-Algo

[[I-D.zhu-lsr-isis-sr-vtn-flexalgo](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#ref-I-D.zhu-lsr-isis-sr-vtn-flexalgo)] or the combination of these

mechanisms in the control plane. This mechanism is suitable for

networks where a small number of network resource partitions are

needed. As the number of network resource partitions increases,

there may be several scalability challenges with this approach:

1. The number of SR SIDs needed will increase in proportion to the

number of network resource partitions in the network, which will

bring challenges both to the distribution of SIDs and the related

information in the control plane, and to the installation of

forwarding entries for resource aware SIDs in the data plane.

2. The number of route computation (e.g. SPF computation) will

increase in proportion to the number of network resource

partitions in the network, which may introduce significant

overhead to the control plane of network nodes.

Dong, et al. Expires 20 June 2022 [Page 8]

Internet-Draft NRP Scalability Considerations December 2021

3. The maximum number of logical topologies supported by OSPF is

128, and the maximum number of Flex-Algo is 128, which may not

meet the required number of network resource partitions in some

network scenarios.

[**4**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-4)**. Proposed Scalability Optimizations**

[**4.1**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-4.1)**. Control Plane Optimizations**

For the distributed control plane, several optimizations can be

considered to reduce the control plane overhead and improve the

control plane scalability.

The first optimization mechanism is to reduce the amount of control

plane sessions used for the establishment and maintenance of the

network resource partitions. For multiple network resource

partitions which have the same connection relationship between two

adjacent network nodes, it is proposed that one single control

protocol session is used for such group of network resource

partitions. The information of different network resource partitions

can be exchanged over the same session, with necessary identification

information to distinguish the network resource partitions in the

control message. This could reduce the overhead of maintaining a

large number of separate control protocol sessions for each network

resource partition, and could also reduce the amount of control plane

messages flooded in the network.

The second optimization mechanism is to decouple the network resource

partition information from the associated logical topology

information in the control plane, so that the resource attributes and

the topology attributes can be advertised and processed separately.

In a network, it is possible that multiple network resource

partitions associate with the same logical topology, and multiple

network resource partitions may share the same set of network

resources on a subset of network nodes and links. Then it is more

efficient if only one copy of the topology information is advertised,

and multiple network resource partitions sharing the same topology

could refer to this topology information. More importantly, with

this approach, the result of topology-based route computation could

be shared by multiple network resource partitions, so that the

overhead of per network resource partition route computation could be

avoided. Similarly, information of a subset of network resources

reserved on a particular network node or link could be advertised

once and may be referred to by multiple network resource partitions

which share the same set of resources.

Dong, et al. Expires 20 June 2022 [Page 9]

Internet-Draft NRP Scalability Considerations December 2021

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# # # \* \* \*

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NRP-1 NRP-2

O-----O-----O

| | |

| | |

O-----O-----O

Shared Network Topology

Legend

O Virtual node

### Virtual links with a set of reserved resources

\*\*\* Virtual links with another set of reserved resources

Figure 2. Topology Sharing between Network Resource Partitions

Figure 1: FIG-2

Figure 2 gives an example of two network resource partitions which

share the same logical topology. As shown in the figure, NRP-1 and

NRP-2 are associated with the same topology, while the resource

attributes of each network resource partition are different. In this

case, only one copy of the network topology information needs to be

advertised, and the topology-based route computation result can be

shared by the two network resource partitions to generate the

corresponding routing and forwarding tables.

O#####O#####O O----O#####O

# # # \/ # #

# # # /\ # #

O#####O#####O O----O#####O

NRP-1 NRP-2

Legend

O Virtual node

### Virtual links with a set of reserved resource

--- Virtual links with another set of reserved resource

Figure 3. Resource Sharing between Network Resource Partitions

Dong, et al. Expires 20 June 2022 [Page 10]

Internet-Draft NRP Scalability Considerations December 2021

Figure 3 gives another example of two network resource partitions

which share the same set of network resources on some of the links.

In this case, information about the resources allocated on each link

only needs to be advertised once, then both NRP-1 and NRP-2 could

refer to the reserved link resource for constraint based path

computation.

For the optimization of the centralized control plane, it is

suggested that the centralized controller is used as a complementary

mechanism to the distributed control plane rather than a replacement,

so that the workload for network resource partition specific path

computation in control plane could be shared by both the centralized

controller and the network nodes, and the scalability of both systems

could be improved.

[**4.2**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-4.2)**. Data Plane Optimizations**

To support more IETF network slice services while keeping the amount

of data plane state at a reasonable scale, one typical approach is to

classify a set of IETF network slice services which have similar

service characteristics and performance requirements into a group,

and such group of IETF network slice services are mapped to one

network resource partition, which is allocated with an aggregated set

of network resources and the union of the required logical topologies

to meet the service requirement of the whole group of IETF network

slice services. Different groups of IETF network slice services can

be mapped to different network resource partitions with different set

of network resources allocated from the underlay network. With

appropriate grouping of IETF network slice services, a reasonable

number of network resource partitions with network resources

reservation and aggregation could still meet the IETF network slice

service requirements.

Another optimization in the data plane is to decouple the identifiers

used for topology-based forwarding and the identifier used for the

resource-specific processing introduced by network resource

partition. One possible mechanism is to introduce a dedicated

Network Resource Partition Identifier (NRP-ID) in the packet header

to uniquely identify the set of local network resources allocated to

a network resource partition on each network node for the processing

and forwarding of the received packets. Then the existing

identifiers in the packet header used for topology based forwarding

(e.g. the destination IP address, MPLS forwarding labels) are kept

unchanged. The benefit is the amount of the existing topology-

specific identifiers will not be impacted by the increasing number of

network resource partitions. Since this new NRP-ID field will be

used together with other existing fields to determine the packet

forwarding behavior, this may require network nodes to support a

Dong, et al. Expires 20 June 2022 [Page 11]

Internet-Draft NRP Scalability Considerations December 2021

hierarchical forwarding table in data plane. Figure 4 shows the

concept of using different data plane identifiers for topology-

specific and resource-specific packet forwarding and processing

respectively.

+--------------------------+

| Packet Header |

| |

| +----------------------+ |

| | Topology-specific IDs| |

| +----------------------+ |

| |

| +----------------------+ |

| | NRP-ID | |

| +----------------------+ |

+--------------------------+

Figure 4. Decoupled Topology and Resource Identifiers in data packet

In an IPv6 [[RFC8200](https://datatracker.ietf.org/doc/html/rfc8200)] based network, this could be achieved by

introducing a dedicated field in either the IPv6 fixed header or the

extension headers to carry the NRP-ID for the resource-specific

forwarding, while keeping the destination IP address field used for

routing towards the destination prefix in the corresponding topology.

Note that the NRP-ID needs to be parsed by every node along the path

which is capable of network resource partition aware forwarding.

[[I-D.dong-6man-enhanced-vpn-vtn-id](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#ref-I-D.dong-6man-enhanced-vpn-vtn-id)] introduces the mechanism of

carrying the VTN resource ID (which is equivalent to NRP-ID in the

context of network slicing) in IPv6 Hop-by-Hop extension header.

In an MPLS [[RFC3032](https://datatracker.ietf.org/doc/html/rfc3032)] based network, this may be achieved by

introducing a dedicated NRP-ID either in the MPLS label stack or

following the MPLS label stack. This way, the existing MPLS

forwarding labels are used for topology-specific packet forwarding

towards the destination node, and the NRP-ID is used to determine the

set of network resources for packet processing. This requires that

both the forwarding label and the NRP-ID be parsed by nodes along the

forwarding path of the packet, and the forwarding behavior may depend

on the position of the NRP-ID in the packet. The detailed extensions

to MPLS data plane are out of the scope of this document.

[**5**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-5)**. Solution Evolution for Improved Scalability**

Based on the analysis in this document, the control plane and data

plane for network resource partition needs to evolve to support the

increasing number of IETF network slice services and the increasing

number of network resource partitions in the network.

Dong, et al. Expires 20 June 2022 [Page 12]

Internet-Draft NRP Scalability Considerations December 2021

At the first step, by introducing resource-awareness to segment

routing SIDs [[I-D.ietf-spring-resource-aware-segments](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#ref-I-D.ietf-spring-resource-aware-segments)], and using

Multi-Topology or Flex-Algo as the control plane mechanism to define

the logical topology, it could provide a solution for building a

limited number of network resource partitions in the network, and can

meet the requirement of a relatively small number of IETF network

slice services. This mechanism is called the basic SR based NRP.

As the required number of IETF network slice services increases, more

network resource partitions may be needed, then the control plane

scalability could be improved by decoupling the topology attribute

from the resource attribute, so that multiple network resource

partitions could share the same topology or resource attribute to

reduce the control plane and data plane overhead. The data plane can

still be based on the resource-aware SIDs. This mechanism is called

the scalable SR based NRP. Both the basic and the scalable SR based

NRP mechanisms are described in

[[I-D.ietf-spring-sr-for-enhanced-vpn](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#ref-I-D.ietf-spring-sr-for-enhanced-vpn)].

When the data plane scalability becomes a concern, a dedicated NRP-ID

can be introduced in the data packet to decouple the resource-

specific identifiers from the topology-specific identifiers in the

data plane, this could help to reduce the number of IP addresses or

SR SIDs needed to support a large number of network resource

partitions. This mechanism is called the NRP-ID based mechanism.

[**6**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-6)**. Security Considerations**

This document describes the scalability considerations about the

network control plane and data plane of network resource partitions

in the realization of IETF network slice services, and proposes the

mechanisms for scalability optimization. The security considerations

in[I-D.ietf-teas-ietf-network-slices] and

[[I-D.ietf-teas-enhanced-vpn](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#ref-I-D.ietf-teas-enhanced-vpn)] applies to this document.

[**7**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-7)**. IANA Considerations**

This document makes no request of IANA.

[**8**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-8)**. Contributors**

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Dong, et al. Expires 20 June 2022 [Page 13]

Internet-Draft NRP Scalability Considerations December 2021

[**9**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-9)**. Acknowledgments**

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[**10**](https://datatracker.ietf.org/doc/html/draft-dong-teas-nrp-scalability-00#section-10)**. References**

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Dong, et al. Expires 20 June 2022 [Page 16]

Internet-Draft NRP Scalability Considerations December 2021

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Dong, et al. Expires 20 June 2022 [Page 17]