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IETF Definition of Transport Slice

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Abstract

This document describes the definition of a slice in the transport

networks and its characteristics. The purpose here is to bring

clarity and a common understanding of the transport slice concept and

describe related terms and their meaning. It explains how transport

slices can be used in end to end network slices, or independently.

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1. Introduction

A number of use cases benefit from establishing network connectivity

providing transport and assurance of a specific set of network

resources. In this document, as detailed in subsequent sections, we

refer to this connectivity and resource commitment as transport

slices. Services that might benefit from the transport slices

include:

o 5G services (e.g. eMBB, URLLC, mMTC)(See [TS.23.501-3GPP])

o Network wholesale services

o Network infrastructure sharing among operators

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o NFV connectivity and Data Center Interconnection

o VPNs with specific characteristics

This document defines the concept of transport slices that provide

connectivity with specific commitment of network resources between a

number of end points over a shared network infrastructure.

Transport slices are created and managed within the scope of one or

more underlying network technologies (e.g. IP, MPLS, optical).

These transport slices are expected to enable a diverse set of

applications, that have different requirements on communication, to

gracefully coexist on the same network infrastructure.

Transport slices relate to a more general topic of network slicing.

It is not the goal of this document to define this broader concept,

but in general, it is a methodology to describe the logical (or

abstract) partitioning of network resources associated with a service

or an application.

1.1. Rationale

Transport slice is described as a construct that specifies connectivity requirements with an emphasis on assurance of those requirements. Transport slices are unaware of any underlying infrastructure connectivity (hence, the term ‘transport’). The types of underlying provider networks can be based on any combination of IP, Ethernet, MPLS and Optical technologies.

Existing VPN (L2 or L3) network- and particularly service- models come close but the difference being a user of transport slice does not concern with the specific details related to connectibity, such as what are the provider addresses, VRFs, or what routing protocols to use, and so on. In cases where customers need more control over network technology aspects, direct use of VPN technologies or service models will be more suitable.

Transport slices also include specification of resources relating to network functions that are necessary for several customer applications. Thus, the goal of transport slice is to serve as a generic SLO-assured connectivity construct over different kinds of underlying infrastructures.

2. Terms and Abbreviations

The terms and abbreviations used in this document are listed below.

o E2E NS: End to End Network Slice

o TS: Transport Slice

o TSC: Transport Slice Controller

o EP: Endpoint

o EU: End User

o NBI: NorthBound Interface

o SBI: SouthBound Interface

o SLI: Service Level Indicator

o SLO: Service Level Objective

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o SLA: Service Level Agreement

3. Definition and Scope of Transport Slice

The definition of a transport slice is as follows:

"A transport slice is a logical network topology connecting a number of endpoints and a set of shared or dedicated network resources,

which are used to satisfy specific Service Level Objectives (SLO)".

The text below describes transport slices in more detail.

A transport slice consists of a set of connections between multiple

endpoints with a specified connectivity type and one or more SLOs associated with it. SLOs are used to describe different characteristics of network resources associated with the service delivered and corresponding parameters necessary to realize the transport slice.

Transport slice specification should be technology-agnostic, and the

means for transport slice realization can be chosen depending on

several factors such as service requirements, specifications or

capabilities of underlying infrastructure. The structure and

different characteristics of transport slices are described in the

following sections.

A transport slice consists of a set of connections between multiple endpoints with a specified connectivity type and one or more SLOs. Note that a subset of transport slice connections can have a SLO. The SLO is typically defined symmertically but might be defined asymmetrically. Connectivity types might be P2P, P2MP, MP2MP, uni-direction and bi-direction.

SLOs are used to describe service behavior which imply different network resources to be associated with the service delivered as necessary to realize the transport slice.

The term ‘transport’ in transport slice is derived from the definition of Transport Network in the section 1.3.1 of RFC5921 ‘A Transport Network provides transparent transmission of user traffic between attached client devices by establishing and maintaining point-to-point or point-to-multipoint connections between such devices’. ‘Slice’ refers to the characteristics that separate one type of user-traffic from other types of traffic. Thus, transport slice assumes that an underlying transport network has capability to change the configurations of the network nodes on demand, through in-band signaling or via controller(s) and to provide transport transmissions with fulfilling all or some of SLOs to specific flows.

4. Transport Slice Characteristics

The following subsections describe the characteristics needed for

support of transport slices.

4.1. Service Level Objectives for Transport Slices

A transport slice is defined in terms of several quantifiable characteristics or

service-level objectives (SLOs). These objectives define a set of

network resource parameters or values necessary to provide a service

as requested for a given transport slice. SLOs will not describe

'how' will transport slices will be implemented or realized in the

underlying networks. They will instead be defined in terms of

dimensions of operations (time, capacity,...),

availability and other attributes. A transport slice can have one or

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more SLOs. The SLO values can be defined in each direction

and for specific subsets of two or more endpoints (i.e. for a subset

of connections in transport slice).

The values of requested SLOs should be clearly specified. It should

be possible to monitor and measure the performance of transport

slices against the requested SLOs and verify that they are being met.

Some SLOs can be measured directly through collection of metrics or statistics

collected from the network, while others are deduced from measurable

objectives and may require additional tools or mechanisms to measure

their target values.

Note that this document defines a minimal set of SLOs and later systems or standards could extend this set and define more SLOs. For example, we included Guaranteed bandwidth which is the minimum requested bandwidth for the transport slice. The later standard might define other SLOs related to bandwidth if needed.

Accordingly, SLOs can be categorized in to

'Directly Measurable Objectives' or 'Indirectly Measurable

Objectives' as follows.

Some of the 'Directly Measurable Objectives' are:

o Guaranteed Bandwidth

o Guaranteed Maximum Latency

* Maximum permissible delay variation
* Maximum permissible packet loss rate
* Availability

o

o Other objectives could be specified

Some of the 'Indirectly Measurable Objectives' are:

* Security

o Other objectives such as geographical restrictions, maximum occupancy level, etc. could be specified

The definition of these objectives are as follows:

o Guaranteed Bandwidth: Minimum requested bandwidth between two endpoints. The bandwidth is measured in data rate units of bits per second and can be requested unidirectionally.

o Guaranteed Maximum Latency: Maximum permissible network delay when

transmitting between two endpoints. The latency is measured in

terms of network characteristics (excluding application-level

latency). [RFC2681] and [RFC7679] discuss round trip times and

one-way metrics, respectively.

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o Maximum permissible delay variation: Packet delay variation (PDV)

as defined by [RFC3393], is measured by the difference in the one-

way delay between sequential packets in a flow. Minimizing

variations in the delay are important for real-time applications.

o Maximum permissible packet loss rate: is defined by the

ratio of received packets dropped to packetstransmitted between two endpoints. See [RFC7680]

o

o Availability: It a measure of how often a customer defined service

is lost or degraded to the point of unacceptable performance due

to any fault in the network. It is a ratio of time the transport

slice meets agreed SLO over the total time where the transport

slice is contracted.

o Security: This objective may request for encryption [RFC4303] between two end-points explicitly to meet architecture recommendations as in [TS33.210] or for compliance [HIPAA][PCI]. Other security requests can be made as specified in [I2NSF].

Note: Security violations are difficult to observe and cannot be measured as quantifiable metric. Still, the user of transport slice should be able to

request certain criteria for compliance and be able to identify exceptions and unexpected traffic. For this purpose [i2nsf-nsf-monitoring-data-model-06] can be leveraged.

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[Kiran please add an example and more clarify for “NF resources”.]

[Eric mentioned that per flow shall be removed]

[Kiran: The purpose is not to add the SLO per-flow but mainly number of flows supported.]

We need to clarify the IP flow.

[Jie, we address the ip address assignment if needed]

[Eric: why needed traffic type?]

Additional objectives may be necessary, such as specifying specific

characteristics/ well defined paths or domains that a slice may

transit. A transport slice carries multiple flows between the 2

endpoints, therefore objectives should also say if they are

aggregates or on per flow basis and in such case to be specific

enough for the system to be able to identify these specifics (subset

of flows).

Optionally, other traffic characteristics may be requested. These

include for example MTU, traffic type (e.g., IPv4, IPv6, Ethernet,

unstructured. A transport slice carries multiple flows between the 2

endpoints, therefore objectives should also say if they are for the

entire connection, group of flows or on per flow basis. Flow

characteristics of a transport slice should specify the scale of the

flows (i.e. maximum number of accommodatable flows) and optionally a

maximum number of countable rosurce units, e.g IP or MAC addresses a

slice might consume.

Further description of a set of measurable attributes is captured in

[I-D.contreras-teas-slice-nbi].

4.2. Endpoint Variation

Transport slice endpoints are the terminating or originating nodes

requiring connectivity with specific SLO. Endpoints may be

termination points on devices or functions.

4.2.1. Types of Endpoints

There are two types of endpoints based on the functions they perform.

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Transport Slice endpoint: These endpoints are the headends and

tailends of connections in transport slice where they perform

the forwarding of the customer payload.

Transport slice realization endpoint: Transport slice realization endpoint: These endpoints are related to

the realization of the transport slice where they manipulate,

process or modify the user data payload. In some scenarios, it

is possible that the 'Transport slice endpoints' and 'Transport

slice realization endpoints' are identical. A non-exhaustive list

of devices which contains service endpoints are routers, switches,

roufirewalls, WAN and application acceleration, Deep Packet

The concept of the transport slice endpoints and transport slice

realization endpoints are conceptually similar to the concept of

connection points defined in [I-D.ietf-teas-sf-aware-topo-model] and

access points defined in [RFC8453] but they are not the same.

4.2.2. Connectivity patterns within Transport Slice

The transport slices are a group of connections among a set of

endpoints. These connections can be point to point (P2P), point to

multipoint (P2MP), multi-point to point (MP2P), or multi-point to

multi-point (MP2MP) based on the topology requested by the customer.

4.3. Vertical Transport Slice

Transport slice may follow a hierarchical relationship that would

provide a vertical structure to it. This is used for building multi-

layer slices in which each layer provides an abstraction, as well as

an independent monitoring, performance, control and management of the

resources. The vertical transport slice characteristic maybe used in

2 forms:

o The Transport slice itself where it represents a hierarchy of

abstracted transport slices. In this case, realization will be

done just once with a particular technology. Thus, the lowest

transport slice in the hierarchy that can not be decomposed

further will be one to one mapping to its instance of realized

transport slice.

o Each layer (physical, datalink, or IP) has its own set of

resources that can be provided to the upper layer as a transport

slice. Thus, transport slice at one layer is used by the layer

above. This type of multi-layer vertical transport slice

associates resources at different layers. For example, an IP

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transport slice would utilize one or more optical transport slice.

In this case, realization will be done for a particular technology

at that particular layer. Thus, the lowest transport slice in

this type of hierarchy that can not be decomposed further will be

an instance of realized physical layer transport slice.

<======================== TS1 ========================>

<=====TS11=======> <==============TS12===============>

<====TS121====> <=====TS122======>

.--. .--. .--.

( )--. ( )--. ( )--.

.' ' .' ' .' '

[EU-x] ( Network-1 ) ( Network-2 ) ... ( Network-3 ) [EU-y]

`-----------' `-----------' `----------'

| | |

| Operator-y | Operator-z |

Legend:

TSnnn: Level 3 vertical transport slice nnn

TSnn: Level 2 vertical transport slice nn

TSn: Level 1 transport Slice n

Figure 1: Transport Slice Vertical and Horizontal Composition

Figure 1 shows the transport slice hierarchy. Slices TS11 and TS12

are composed together to form TS1 that is the top level transport

slice definition, TS121 and TS122 collectively define TS12. The SLO

for bandwidth guarantee will be shared and latency guarantee will be

split into latency in networks 2 and 3. To emphasize the

hierarchical structure, consider Network-2 and Network-3 are in the

same administrative domain but use different transport technologies

SR and L2VPN respectively. Then instead of presenting 2 transport

slices, Operator-z can expose only one transport slice TS12

abstracting the underlying transport technology details.

Note: The specification to connect TS121 and TS122 are similar to

those connecting TS12 and TS11.

4.4. Horizontal Composition of Transport slice

In contrast, horizontal transport slices enable the composition of

multiple realized transport slices. Since transport slices are not

necessarily a single encapsulation tunnel and may traverse through

different data planes, each realized transport slice will require a

stitching, interworking or mapping function. These stitching

functions can be viewed as a type of intermediate network function

endpoints. For instance in Figure 1, TS11 and TS12 are horizontal

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transport slices. If we assume that TS11 is an L2 tunnel and TS12 is

an SRV6 based path, then a 'Service type EP' (not shown in the

figure) is needed for translation.

Author's notes: This service type EP is a new type of transport slice

specific service function. We may call it transport slice gateway.

5. Transport Slice Detailed Description

A transport slice is a set of connections among various endpoints to

form a logical network. The goal is to achieve specific SLO for a

customer as shown in Figure 2. The endpoints may be user equipment,

any physical or virtual network functions (PNF/VNF), or any network

service for that matter. Similarly, the connections may be virtual

or physical links of any type of technology.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

[EP11]------/ /--[EP21]

/ /

[EP12]----/ Transport Slice /----[EP22]

: / (SLOs e.g. /

: / B/W > x bps, Delay < y ms)/

[EP1m]-/\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_/-------[EP2n]

== == == == == == == == == == == == == == == == == ==

.--. .--.

[EP11] ( )- . ( )- . [EP21]

.' ' SLO .' '

[EP12] ( Network-1 ) ... ( Network-p ) [EP22]

: `-----------' `-----------' :

[EP1m] [EP2n]

Legend

SLOs in terms of attributes, e.g. BW, delay.

EP: Endpoint

B/W: Bandwidth

Figure 2: Transport slice

Figure 2 illustrates a case where a transport slice provides

connectivity between a set of endpoints pairs with specific

characteristics for SLO (e.g. guaranteed minimum bandwidth of x bps

and guaranteed delay of less than y ms). The endpoints may be

distributed in the underlay networks, and a transport slice can be

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deployed across multiple network domains. Also, the endpoints on the

same transport slice may belong to the same address space.

The "Transport Slices" provides various connections with certain SLO

between various endpoints whereas the transport slice realization

addresses its implementation using various technologies. In short,

the transport slice involves both its definition and its realization;

the transport slice definition addresses the set of connectivities

with required SLOs whereas the transport slice realization addresses

how this transport slice is deployed in the network for certain

network technologies.

A transport slice is built based on a request from a higher level

operation system. The interface to higher operations systems should

express the needed connectivity in a technology-agnostic way, and

slice customers don't need to recognize concrete configurations based

on the technologies (e.g. being more declarative than imperative).

The request to instantiate a transport slice is represented with some

indicators such as SLO, and technologies are selected and managed

accordingly.

In the context of network slices, the term sub-slice or slice-subnet

comes up in other standard organizations, however, w.r.t. the IP/MPLS

based transport networks these terms are all equivalent.

Furthermore, the structure of transport slices may be layered

vertically or composed horizontally, i.e. operationally, a transport

slice maybe decomposed in two or more transport slices which are then

independently realized and managed. This is further described in

Section 4.3.

5.1. Stakeholders

A transport slice and its realization involves the following

stakeholders and it is relevant to define them for consistent

terminology.

Customer or User: A customer is a user of transport slice.

Customers may request for monitoring of associated resources or

specific changes to them. A user may either directly manage its

service by interfacing with the transport slice controller or

indirectly through an orchestrator.

Orchestrator: An orchestrator is an entity that aggregates different

services, resource and network requirements. It interfaces with

the transport slice controllers.

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Transport Slice Controller (TSC): It realizes a transport slice in

the network, maintains and monitors the run-time state of

resources and topologies associated with it. A well-defined

interface is needed between different types of transport slice

controller and different types of orchestrator. A transport slice

operator (or slice operator for short) manages one or more

transport slices using the Transport Slice Controller(s).

Transport Network Controller: is some form of network infrastructure

controller that offers network resources to TSC to realize a

particular transport slice. These may be existing network

controllers associated with one or more specific technologies that

may be adapted to the function of realizing transport slices in a

network.

5.2. Transport Slice Controller Interfaces

The interworking and inter-operability among the different

stakeholders is required to provide common means of provisioning,

operating and monitoring the transport slices. The following

communication interfaces are identified (see Figure 3).

TSC Northbound Interface (NBI): The TSC Northbound Interface is an

interface between a higher level system, e.g. 'E2E network slice

orchestrator' and the 'Transport slice controller'. It is a

technology agnostic interface. Over this NBI, slice

characteristics and other requirements can be informed to TSC and

current state of a transport slice may be requested.

TSC Southbound Interface (SBI): The TSC Southbound Interface is an interface between 'Transport

slice controller (TSC)' and network controller(s). These

interfaces are technology-specific and can utilize many of the

network models.

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

| Customer |

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

A

|

V

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

| A higher level system |

| (e.g e2e network slice orchestrator) |

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

A

| TSC NBI

V

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

| Transport Slice Controller |

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

A

| TSC SBI

V

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

| Network Controller(s) |

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

Figure 3: Interface of Transport Slice Controller

5.3. Transport slice Realization

Realization of a Transport Slice is a mapping of underlying

infrastructure with its definition. It is technology specific entity

that is created and maintained over southbound interfaces. The

Network controller(s) export the connectivity and resource mappings

to the TSC. The network controller abstracts the details of

underlying resources from the TSC.

The realization may be achieved in the form of either physical or

logical connectivity through VPNs, a variety of tunneling

technologies such as segment routing, SFC, etc. Accordingly,

endpoints may be realized as physical or logical service or network

functions.

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6. Relationship with End-to-End Network Slicing

An end-to-end (E2E) network slice is a complete logical network that

provides a service in its entirety with a specific assurance to the

customer. A transport slice concerns with those assurance aspects

only within the transport networks. Consider Figure 4, where a

network operator has an E2E network slice that traverses multiple

technology-specific networks. Each of these networks might use any

number of technologies, including but not limited to IP, MPLS, Fiber-

Optics (e.g. WDM, DWDM), Passive Optical Networking (PON),

Microwave, etc.

Each of these networks includes multiple (physical or virtual) nodes

and may also provide network functions beyond simply carrying of

technology-specific protocol data units. The types of nodes used in

any of these networks may include:

o Packet/frame processing nodes (e.g., Routers, Switches)

o Application servers

o Service Functions(e.g., Firewall, Loadbalancer)

o Radio Access Network (RAN) components

o Mobile Core components

o Microwave transceivers

o Optical repeaters

o etc.

Each network may support different technologies and an E2E network

slice is a combination of these networks. As an example:

o Network 1 might contain multiple 5G RAN nodes connected to a few

Cell Site Gateways (CSG) routers.

o Network 2 might have one or more layer-3 routers and layer-2

switches which may run on top of an optical network.

o Network 3 might have a number of 5G RAN nodes connected to Passive

Optical Network (PON) switches.

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<======================= E2E NS ======================>

<-OS1-> <-TS1-> <-TS2-> <-OS2-> ... <-TSn-> <-OSm->

|------------------------------------------------------|

| .--. .--. .--. |

| ( )--. ( )--. ( )--. |

| .' ' .' ' .' ' |

[EU-x] | ( Network-1 ) ( Network-2 ) ... ( Network-p ) |[EU-y]

| `-----------' `-----------' `----------' |

| |

| Operator-z |

|------------------------------------------------------|

Legend:

E2E NS: End-to-end network slice

TSn: Transport Slice n

OSm: Other Slice m

EU-x: End User-x

EU-y: End User-y

Figure 4: E2E network slice

When an operator-z creates a specific E2E network slice, it may

create one or more of transport slices and other slices (application

logic or other system functions).

An independent E2E logical network (called E2E network slice) is

created for a service (e.g. CCTV, autonomous driving, HD map, etc.)

with a specific network SLO requirement e.g. a secure connection with

an E2E latency less than 5ms, from End User-x (EU-x) to End User-y

(EU-y). EU-x maybe a 5G user equipment such as an infotainment unit

in a car, CCTV, or a car for autonomous driving, etc. and EU-y in 5G

is 5G application server, IMS, etc.

In Figure 4, "E2E NS" is that logical network with requested SLO

between EU-x to EU-y and is associated with a customer and a specific

service type.

7. Security Considerations

TBD

8. IANA Considerations

This memo includes no request to IANA.

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9. Acknowledgment

The entire TEAS NS design team and everyone participating in those

discussion has contributed to this draft. Particularly, Eric Gray,

Xufeng Liu, Jie Dong, Jeff Tantsura, and Jari Arkko for a thorough

review among other contributions.

10. Appendix A

10.1. On Meeting guarantees of service objectives

Due to overloading of the term, a further discussion is added to

highlight two aspects of isolation, first the resolution of isolation

of an objective (as described above) and second, the dedicated use or

a hard-separation perspective of the resource.

Providing a hard resolution of guarantee for the characteristics of a

transport slice means that the behavior and performance of other

transport slices should not impact that slice, even if they run over

the same underlying infrastructure or use logically shared network

resources.

In the context of soft resolution of guarantees, since the transport

slices are logically partitioned over the shared resources, a certain

degree of commitment to the guarantee is expected even when it is not

hard. When the shared resource pools begin to become saturated, SLO

violations can happen, however, impacting only the performance or

operation of service associated with the transport slice.

This degree of isolation can be derived from availability

characteristics requested, such as whether a hard or soft guarantee

was requested. Requesting a hard guarantee may commit more resources

than would be required for a softer limit.

In addition, resource isolation may be applied to ensure dedicated

access to a particular node, for instance. In such requests a

dedicated allocation to a link, node and/or other resources to create

a transport slice for a particular service. For example, a mission-

critical service may ask for a dedicated router and/or a link or port

for complete isolation from other services.

When realizing a transport slice, a network controller should be

responsible for allocating and providing resources according to the

specified objectives.

SLO violations can occur for two reasons and corresponding statements

apply

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o Shared resource interference: i.e. multiple transport slices

simultaneously share the same resource, and one of them consume

the resource in surplus. If the SLO guarantees are strictly

required, then the network controller can be informed of this by

requesting a hard guarantee. Note that the terms hard and soft

limit are requirement oriented and different from what is

specified in, [I-D.ietf-teas-enhanced-vpn]).

o Resource failure or fault occurs, such as a link or node failure.

Where it is important to defend against these, the relevant

characteristics on resource redundancy (and perhaps some other

characteristics on restoration speed and other factors) need to be

specified.

\* Restoration isolation: the network is not impacted for a period

longer than the given time. For example, failover or the

service restoration takes no longer than some number of

seconds. This is specified by Availability SLO.

\* Protection isolation: the network path is protected with

specified backup path. This is specified by Availability SLO.

SLA vs SLO discussion: In defining transport slices, the term SLO

instead of SLA is used even though SLAs are more commonly used term

by the operators. SLOs are definitive and measurable parameters

associated with a service, therefore, network resource and

connectivity requirements are defined accurately. In contrast,

service level agreements represent contracts for a service between a

service provider and a service consumer (or subscriber). Providers

then translate SLA into SLO; these translations vary from one service

provider to the other. Therefore, all through within the scope of

transport slices term SLO will be used.

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