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                    Cooperating Layered Architecture for SDN
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Abstract

   Software Defined Networking proposes the separation of the control
   plane from the data plane in the network nodes and its logical
   centralization on a control entity. Most of the network intelligence
   is moved to this functional entity. Typically, such entity is seen
   as a compendium of interacting control functions in a vertical, tight
   integrated fashion. The relocation of the control functions from a
   number of distributed network nodes to a logical central entity
   conceptually places together a number of control capabilities with
   different purposes. As a consequence, the existing solutions do not
   provide a clear separation between transport control and services
   that relies upon transport capabilities.

   This document describes a proposal named Cooperating Layered
   Architecture for SDN. The idea behind that is to differentiate the
   control functions associated to transport from those related to
   services, in such a way that they can be provided and maintained
   independently, and can follow their own evolution path.

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1. Introduction

   Software Defined Networking (SDN) proposes the separation of the
   control plane from the data plane in the network nodes and its
   logical centralization on a control entity. A programmatic interface
   is defined between such entity and the network nodes, which
   functionality is supposed to perform traffic forwarding (only).
   Through that interface, the control entity instructs the nodes
   involved in the forwarding plane and modifies their traffic
   forwarding behavior accordingly.

   Most of the intelligence is moved to such functional entity.
   Typically, such entity is seen as a compendium of interacting control
   functions in a vertical, tight integrated fashion.

   This approach presents a number of issues:

   o Unclear responsibilities between actors involved in a service
      provision and delivery.

   o Complex reuse of functions for the provision of services.

   o Closed, monolithic control architectures.

   o Difficult interoperability and interchangeability of functional
      components.

   o Blurred business boundaries among providers.

   o Complex service/network diagnosis and troubleshooting,
      particularly to determine which segment is responsible for a
      failure.

   The relocation of the control functions from a number of distributed
   network nodes to another entity conceptually places together a number
   of control capabilities with different purposes. As a consequence,
   the existing solutions do not provide a clear separation between
   services and transport control.

This document describes a proposal named Cooperating Layered
Architecture for SDN (CLAS). The idea behind that is to
differentiate the control functions associated to transport from
those related to services, in such a way that they can be provided
and maintained independently, and can follow their own evolution
path.

Despite such differentiation it is required a close cooperation
between service and transport layers and associated components to
provide an efficient usage of the resources.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
"SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
document are to be interpreted as described in RFC2119 [RFC2119].

This document makes use of the following terms:

o Transport: denotes the transfer capabilities offered by a
   networking infrastructure. The transfer capabilities can rely
   upon pure IP techniques, or other means such as MPLS or optics.

o Service: denote a logical construct that make use of transport
   capabilities. This document does not make any assumption on the
   functional perimeter of a service that can be built above a
   transport infrastructure. As such, a service can be an offering
   that is offered to customers or be invoked for the delivery of
   another (added-value) service.

o SDN intelligence: refers to the decision-making process that is
   hosted by a node or a set of nodes. The intelligence can be
   centralized or distributed. Both schemes are within the scope of
   this document. The SDN intelligence relies on inputs form various
   functional blocks such as: network topology discovery, service
   topology discovery, resource allocation, business guidelines,
   customer profiles, service profiles, etc. The exact decomposition
   of an SDN intelligence, apart from the layering discussed in this
   document, is out of scope.

Additionally, the following acronyms are used in this document.

CLAS: Cooperating Layered Architecture for SDN

FCAPS: Fault, Configuration, Accounting, Performance and Security

SDN: Software Defined Networking

SLA: Service Level Agreement

3. Architecture overview

Current operator networks support multiple services (e.g., VoIP,
IPTV, mobile VoIP, critical mission applications, etc.) on a variety
of transport technologies. The provision and delivery of a service
independently of the underlying transport capabilities requires a
separation of the service related functionalities and an abstraction
of the transport network to hide the specificities of underlying
transfer techniques while offering a common set of capabilities.

Such separation can provide configuration flexibility and
adaptability from the point of view of either the services or the
transport network. Multiple services can be provided on top of a
common transport infrastructure, and similarly, different
technologies can accommodate the connectivity requirements of a
certain service. A close coordination among them is required for a
consistent service delivery (inter-layer cooperation).

This document focuses particularly on:

o Means to expose transport capabilities to external services.

o Means to capture service requirements of services.

o Means to notify service intelligence with underlying transport
   events, for example to adjust service decision-making process with
   underlying transport events.

o Means to instruct the underlying transport capabilities to
   accommodate new requirements, etc.

An example is to guarantee some Quality of Service (QoS) levels.
Different QoS-based offerings could be present at both service and
transport layers. Vertical mechanisms for linking both service and
transport QoS mechanisms should be in place to provide the quality
guarantees to the end user.

CLAS architecture assumes that the logically centralized control
functions are separated in two functional blocks or layers. One of
the functional blocks comprises the service-related functions,
whereas the other one contains the transport-related functions. The
cooperation between the two layers is considered to be implemented
through standard interfaces.

Figure 1 shows the CLAS architecture. It is based on functional
separation in the NGN architecture defined by the ITU-T in [Y.2011].

Two strata of functionality are defined, namely the Service Stratum, comprising the service-related functions, and the Connectivity Stratum, covering the transport ones. The functions on each of these layers are further grouped on control, management and user (or data) planes.

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                    North Bound Interface


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                              ||
    +------------------------------------||------------+
    | Service Stratum                    ||            |
    |                                     \/            |
    |            ..........................             |
    |            . SDN Controller         .            |
    |            .                        .            |
    |  +--------------+     .        +--------------+ . |
    |  | Resource Pl. |     .        |  Mngmt. Pl.  | . |
    |  |              |<===>.  +--------------+     | . |
    |  |              |     .  | Control Pl.  |     | . |
    |  +--------------+     .  |              |-----+ . |
    |                      .  |              |      . |
    |                      .  +--------------+      . |
    |            ...........................       . |
    |                             /\                 |
    |                             ||                 |
    +------------------------------------||------------+
                                  ||
                                  ||
                                  ||
    +------------------------------------||------------+
    | Connectivity Stratum               ||            |
    |                                     \/            |
    |            ..........................             |
    |            . SDN Controller         .            |
    |            .                        .            |
    |  +--------------+     .        +--------------+ . |
    |  | Resource Pl. |     .        |  Mngmt. Pl.  | . |
    |  |              |<===>.  +--------------+     | . |
    |  |              |     .  | Control Pl.  |     | . |
    |  +--------------+     .  |              |-----+ . |
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    |                      .  +--------------+      . |
    |            ...........................       . |
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    +-------------------------------------------------+
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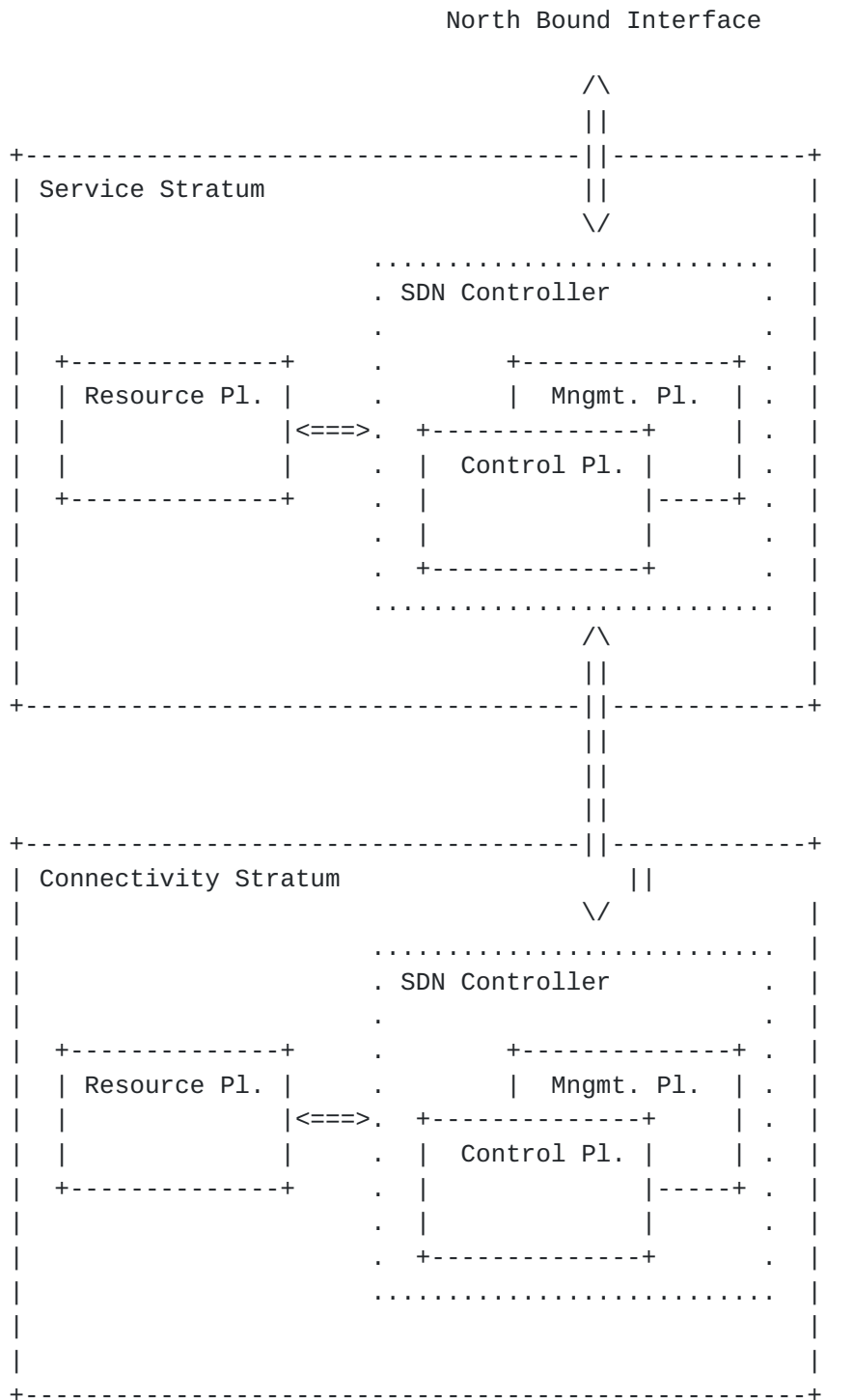
            Figure 1: Cooperating Layered Architecture for SDN

   In the CLAS architecture both the control and management functions
   are the ones logically centralized in one or a set of SDN
   controllers, in such a way that separated SDN controllers are present

in the Service and Connectivity strata. Furthermore, the generic
user or data plane functions included in the NGN architecture are
referred here as resource plane functions. The resource plane in
each stratum is controlled by the corresponding SDN controller
through a standard interface.

The SDN controllers cooperate for the provision and delivery of
services. There is a hierarchy in which the Service SDN controller
requests transport capabilities to the Transport SDN controller.
Furthermore, the Transport SDN controller interacts with the Service
SDN controller to inform it about events in the transport network
that can motivate actions in the service layer.

The Service SDN controller acts as a client of the Transport SDN
controller.

Despite it is not shown in the figure, the Resource planes of each
stratum could be connected. This will depend on the kind of service
provided. Furthermore, the Service stratum could offer an interface
towards external applications to expose network service capabilities
to those applications or customers.

This document does assume that SDN techniques can be enabled jointly
with other distributed means (e.g., IGP).

3.1. Functional strata

As described before, the functional split separates transport-related
functions from service-related functions. Both strata cooperate for
a consistent service delivery.

Consistecy is determined and characterized by the service layer.

Communication between these two components could be implemented using
a variety of means (such as
[I-D.boucadair-connectivity-provisioning-protocol], Intermediate-
Controller Plane Interface (I-CPI) [ONFArch], etc).

3.1.1. Connectivity stratum

The Connectivity stratum comprises the functions focused on the
transfer of data between the communication end points (e.g., between
end-user devices, between two service gateways, etc.). The data
forwarding nodes are controlled and managed by the Transport SDN
component. The Control plane in the SDN controller is in charge of
instructing the forwarding devices to build the end to end data path
for each communication or to make sure forwarding service is
appropriately setup. Forwarding may not be rely on the sole pre-

configured entries; dynamic means can be enabled so that involved
nodes can build dynamically routing and forwarding paths. Finally,
the Management plane performs management functions (i.e., FCAPS) on
those devices, like fault or performance management, as part of the
Connectivity stratum capabilities.

3.1.2. Service stratum

The Service stratum contains the functions related to the provision
of services and the capabilities offered to external applications.
The Resource plane consists of the resources involved in the service
delivery, such as computing resources, registries, databases, etc.
The Control plane is in charge of controlling and configuring those
resources, as well as interacting with the Control plane of the
Transport stratum in client mode for requesting transport
capabilities for a given service. In the same way, the Management
plane implements management actions on the service-related resources
and interacts with the Management plane in the Connectivity stratum
for a cooperating management between layers.

3.1.3. Recursiveness

Recursive layering can happen in some usage scenarios in which the
Connectivity Stratum is itself structured in Service and Connectivity
Stratum. This could be the case of the provision of a transport
services complemented with advanced capabilities additional to the
pure data transport (e.g., maintenance of a given SLA [RFC7297]).

3.2. Plane separation

The CLAS architecture leverages on the SDN proposition of plane
separation. As mentioned before, three different planes are
considered for each stratum. The communication among these three
planes (and with the corresponding plane in other strata) is based on
open, standard interfaces.

3.2.1. Control Plane

The Control plane logically centralizes the control functions of each
stratum and directly controls the corresponding resources. [RFC7426]
introduces the role of the control plane in a SDN architecture. This
plane is part of an SDN controller, and can interact with other
control planes in the same or different strata for accomplishing
control functions.

3.2.2. Management Plane

   The Management plane logically centralizes the management functions
   for each stratum, including the management of the Control and
   Resource planes. [RFC7426] describes the functions of the management
   plane in a SDN environment. This plane is also part of the SDN
   controller, and can interact with the corresponding management planes
   residing in SDN controllers of the same or different strata.

3.2.3. Resource Plane

   The Resource plane comprises the resources for either the transport
   or the service functions. In some cases the service resources can be
   connected to the transport ones (e.g., being the terminating points
   of a transport function) whereas in other cases it can be decoupled
   from the transport resources (e.g., one database keeping some
   register for the end user). Both forwarding and operational planes
   proposed in [RFC7426] would be part of the Resource plane in this
   architecture.

4. Required features

   A number of features are required to be supported by the CLAS
   architecture.

   o Abstraction: the mapping of physical resources into the
      corresponding abstracted resources.

   o Service parameter translation: translation of service parameters
      (e.g., in the form of SLAs) to transport parameters (or
      capabilities) according to different policies.

   o Monitoring: mechanisms (e.g. event notifications) available in
      order to dynamically update the (abstracted) resources' status
      taking in to account e.g. the traffic load.

   o Resource computation: functions able to decide which resources
      will be used for a given service request. As an example,
      functions like PCE could be used to compute/select/decide a
      certain path.

   o Orchestration: ability to combine diverse resources (e.g., IT and
      network resources) in an optimal way.

   o Accounting: record of resource usage.

   o Security: secure communication among components, preventing e.g.
      DoS attacks.

[5](). Communication between SDN Controllers

The SDN Controller residing respectively in the Service and the
Connectivity Stratum need to establish a tight coordination.
Mechanisms for transfer relevant information for each stratum should
be defined.

From the Service perspective, the Service SDN controller needs to
easily access transport resources through well defined APIs to access
the capabilities offered by the Connectivity Stratum. There could be
different ways of obtainign such transport-aware information, i.e.,
by discovering or publishing mechanisms. In the former case the
Service SDN Controller could be able of handling complete information
about the transport capabilities (including resources) offered by the
Connectivity Stratum. In the latter case, the Connectivity Stratum
exposes available capabilities e.g. through a catalog, reducing the
amount of detail of the underlying network.

On the other hand, the Connectivity Stratum requires to properly
capture Service requirements. These can include SLA requirements
with specific metrics (such as delay), level of protection to be
provided, max/min capacity, applicable resource constraints, etc.

The communication between controllers should be also secure,
preventing denial of service.

[6](). Deployment scenarios

Different situations can be found depending on the characteristics of
the networks involved in a given deployment.

[6.1](). Full SDN environments

This case considers the fact that the networks involved in the
provision and delivery of a given service have SDN capabilities.

[6.1.1](). Multiple Service strata associated to a single Connectivity stratum

A single Connectivity stratum can provide transfer functions to more
than one Service strata. The Connectivity stratum offers a standard
interface to each of the Service strata. The Service strata are the
clients of the Connectivity stratum. Some of the capabilities
offered by the Connectivity stratum can be isolation of the transport
resources (slicing), independent routing, etc.

6.1.2. Single service stratum associated to multiple Connectivity strata

A single Service stratum can make use of different Connectivity strata for the provision of a certain service. The Service stratum interfaces each of the Connectivity strata with standard protocols, and orchestrates the provided transfer capabilities for building the end to end transport needs.

6.2. Hybrid environments

This case considers scenarios where one of the strata is legacy totally or in part.

6.2.1. SDN Service stratum associated to a legacy Connectivity stratum

An SDN service stratum can interact with a legacy Connectivity stratum through some interworking function able to adapt SDN-based control and management service-related commands to legacy transport-related protocols, as expected by the legacy Connectivity stratum. The SDN controller in the Service stratum is not aware of the legacy nature of the underlying Connectivity stratum.

6.2.2. Legacy Service stratum associated to an SDN Connectivity stratum

A legacy Service stratum can work with an SDN-enabled Connectivity stratum through the mediation of and interworking function capable to interpret commands from the legacy service functions and translate them into SDN protocols for operating with the SDN-enabled Connectivity stratum.

6.3. Multi-domain scenarios in Connectivity Stratum

The Connectivity Stratum can be composed by transport resources being part of different administrative, topological or technological domains. The Service Stratum can yet interact with a single entity in the Connectivity Stratum in case some abstraction capabilities are provided in the transport part to emulate a single stratum.

Those abstraction capabilities constitute a service itself offered by the Connectivity Stratum to the services making use of it. This service is focused on the provision of transport capabilities, then different of the final communication service using such capabilities.

In this particular case this recursion allows multi-domain scenarios at transport level.

Multi-domain situations can happen in both single-operator and multi-
operator scenarios. Multi-operator scenarios will be addressed in
future versions of the document.

In single operator scenarios a multi-domain or end-to-end abstraction
component can provide an homogeneous abstract view of the underlying
heterogeneous transport capabilities for all the domains.

7. Use cases

This section presents a number of use cases as examples of
applicability of this proposal

7.1. Network Function Virtualization

NFV environments offer two possible levels of SDN control
[ETSI_NFV_EVE005]. One level is the need for controlling the NFVI to
provide connectivity end-to- end among VNFs (Virtual Network
Functions) or among VNFs and PNFs (Physical Network Functions). A
second level is the control and configuration of the VNFs themselves
(in other words, the configuration of the network service implemented
by those VNFs), taking profit of the programmability brought by SDN.
Both control concerns are separated in nature. However, interaction
between both could be expected in order to optimize, scale or
influence each other.

7.2. Abstraction and Control of Transport Networks

To be completed.

8. IANA Considerations

TBD.

9. Security Considerations

TBD. Security in the communication between strata to be addressed.

10. References

10.1. Normative References

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