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              **Multi-domain Service Function Chaining with ALTO**
                  **draft-lachos-multi-domain-sfc-alto-00**

Abstract

   Currently, Service Function Chaining (SFC) that span domains with
   different technology, administration or ownership are being defined
   by the SFC WG.  This document focuses on how the Application Layer
   Traffic Optimization (ALTO) protocol can be used to advertise and
   discover abstract topology, resource and service information from
   different domains, and then compute inter-domain service function
   paths.  Another important concern of this draft is to initiate a
   discussion (ALTO, SFC as well as other WGs) regarding if, how, and
   under what conditions ALTO can be useful to improve the multi-domain
   SFC process.

Requirements Language

   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 RFC 2119 [RFC2119].

Status of This Memo

   This Internet-Draft will expire on January 3, 2019.

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## 1.  Introduction

   The delivery of end-to-end services often requires various Service
   functions (SFs) or Virtual Network Functions (VNFs).  Service
   Function Chaining (SFC) is constructed as an abstract sequence of SFs
   or VNFs [RFC7665].  Multi-domain SFC is the ability to deploy SFC
   across multiple domains with different technology and/or

administration.  To do so, an inter-domain communication process
between different organizations is necessary to (i) exchange
topology, resource and service information, and then (ii) compute
inter-domain service function paths.

The ALTO WG has begun started to discuss the uses of ALTO as an
information model for representing network resource and services in
multi-domain scenarios:

o  [DRAFT-ALTO-BROKER-MDO] proposes an ALTO-based Broker-assisted
   architecture where a broker plane works as a coordinator between a
   set of top-level control planes, i.e., Multi-domain Orchestrator
   (MdOs).  The ALTO services (with the proposed extensions) provides
   abstract maps with a simplified, yet enough information view about
   MdOs involved in the federation.  This information includes the
   abstract network topology, resource availability (e.g., CPUs,
   Memory, and Storage) and capabilities (e.g., supported network
   functions).

o  The document [DRAFT-ALTO-UNICORN] presents Unicorn, a resource
   orchestration framework for multi-domain, geo-distributed data
   analytics.  This work resorts in ALTO as the information model to
   support the accurate, yet privacy-preserving resource discovery
   across different domains.  The key information to be provided by
   the use of ALTO including different types of resources, e.g., the
   computing, storage, and networking resources.

This draft offers concrete use case examples of how ALTO can be
incorporated in the multi-domain SFC architecture.  The examples used
in this document are based on architectures and assumptions currently
being discussed in the SFC WG [DRAFT-HH-MDSFC] and in the ALTO WG
[DRAFT-ALTO-BROKER-MDO] [DRAFT-ALTO-UNICORN].

The overall rationale of this document is to begin a discussion
between the SFC and the ALTO WG (other WGs are welcome) concerning
if, how, and under which conditions ALTO will be helpful in the SFC
traversing different administrative domains.

## 2.  Terminology

This document makes use of the terminology defined in
[DRAFT-HH-MDSFC], [DRAFT-ALTO-UNICORN], and [DRAFT-ALTO-BROKER-MDO].

## 3.  Context and Motivation

Nowadays, different standardization activities (e.g., IETF and ETSI)
and research projects (e.g., 5GEx [H2020.5GEX], 5G-Transformer

[H2020-5G-TRANSFORMER], T-NOVA [T-NOVA], etc.) have been focused on
multi-domain network service chaining.

## 3.1.  Standardization Activities

SFC that span domains owned by multiple administrative entities are
being discussed in the IETF SFC WG.  [DRAFT-HH-MDSFC], for example,
describes SFC crossing different domains owned by various
organizations (e.g., ISPs) or by a single organization with
administration partitions.  The proposed architecture uses a SFC
eXchange Platform (SXP) to collect and exchange information
(topology, service states, policies, etc.) between different
organizations and it works both in centralized (Multiple SFC domains
connected by a logical SXP) and distributed (SXP server as a broker)
environments.  Another IETF initiative is the Network Function
Virtualization Research Group (NFVRG).  The draft "Multi-domain
Network Virtualization" [DRAFT-MD-VIRT] envisions a complete end-to-
end logical network as stitching services offered by multiple domains
from multiple providers.  It also points to the need for creating
solutions that enable the exchange of relevant information (resources
and topologies) across different providers.

The ETSI NFV ISG is paving the way toward viable architectural
options supporting the efficient placement of functions in different
administrative domains.  More specifically, the document
[ETSI-NFV-IFA028] reports different NFV MANO architectural approaches
with use cases related to network services provided using multiple
administrative domains.  Besides, it gives a non-exhaustive list of
key information to be exchanged between administrative domains
(monitoring parameters, topology view, resource capabilities, etc.)
and recommendations related to security to permit the correct and
proper operation of the final service.

## 3.2.  Research projects

Several projects include an architectural model integrating NFV
management with SDN control capabilities to address the challenges
towards flexible, dynamic, cost-effective, and on-demand service
chaining.

[H2020.5GEX] aims to integrate multiple administrations and
technologies through the collaboration between operators in the
context of emerging 5G networking.  [VITAL][T-NOVA] follow a
centralized approach where each domain advertises its capabilities to
a federation layer which will act as a broker.  In order to avoid one
network operator per country or regions, [H2020-5G-NORMA] proposes
the use of management and control into a single virtual domain.
Also, the 5G-Transformer project [H2020-5G-TRANSFORMER] is defining

flexible slicing and federation of transport networking and computing
resources across multiple domains.

## 4.  ALTO for Multi-domain SFC

A "dialogue" between potential domains that will provide multi-domain
SFC could be beneficial for more efficient use of resources and
increasing the SFC performance.  However, constrained knowledge of
the network services and underlying network topology based only on
localized views from the point of view of a single domain limits the
potential and scope for multi-domain SFC.

To enable a highly customized multi-domains SFC, [DRAFT-HH-MDSFC]
proposes a SFC eXchange Platform to realize inter-domain
communication between top-level control planes.  The SXP is a logical
entity deployed in future Software-defined IXP (as a trusted third-
party platform) or built by a single owner between different
networks.

On a high level, the scope of the SXP contains two main tasks:

o  Provide end-to-end visibility through the collection of topology
   information, service states, and policies from different domains.

o  Compute inter-domain service function path to select the service
   function location from multiple candidate domains.

The ALTO protocol [RFC7285] provides abstract network information in
the form of map services that can be consumed by applications in
order to become network-aware and to take optimized decisions
regarding traffic flows.  Recently, ALTO is also being considered in
multi-domain orchestration scenarios [DRAFT-ALTO-UNICORN]
[DRAFT-ALTO-BROKER-MDO], in which an ALTO server can convey inter-
domain network resource and topology information.

In this context, the SXP can take advantage of multi-domain ALTO
services to obtain important inter-domain information to "guide" the
resource/service provider selection process in that the "best" domain
or candidate domains (according to established policies) can be
intelligently selected.  The following ALTO services can be
identified:

## 4.1.  Advantages of using ALTO

ALTO (and customized ALTO extensions) can be used to offer
aggregated/abstracted views on various types of information including
domain-level topology, storage resources, computation resources,
networking resources and PNF/VNF capabilities.  This generic

representation contributing to a more simple and scalable solution
for resource and service discovery in multi-domain, multi-technology
environments.

In case of Multi-domain SFC, the following ALTO services could be
identified:

### 4.1.1.  Inter-domain info discovery with ALTO Property Map

Each domain needs a global view of other potential candidate domains
to know who can provide part of the NF in the SFC.  A brief list of
information to be exchanged between different domains includes:

o  Resource capabilities, applicable to both IT (computing and
   storage) and networking resources participant of the multi-domain
   SFC, to assist on the decision of SFs placement.

o  Access information (e.g., URL) to the orchestrator entry points
   and Service Access Points (SAPs) for a corresponding network/
   domain.

The ALTO Property Map Service [DRAFT-ALTO-PM] can provide a clear
global view of the resource information offered by other domains.
This information allows discovering which candidate domains may be
contacted to deliver the remaining requirements of a requested end-
to-end service deployment.

### 4.1.2.  Inter-domain path computation with ALTO Cost Map

Once the candidate domains are discovered, it is necessary to compute
inter-domain service function path to select the service function
location from those different candidate domains.

The connectivity information among discovered domains can be
retrieved by an ALTO Cost Map service, responding, for instance, a
path vector with the AS-level topology distance between the source
domain and candidate domains.  Moreover, path vector constraints (as
described in the Multi-Cost Map [RFC8189]) can be applied to filter
out the list of unqualified domains.

In case of the Hybrid Hierarchical SFC architecture [DRAFT-HH-MDSFC],
the SXP (or the Path Calculation Element in the top-level control
plane) could use this information to compute multi-domain service
function paths.

5.  Motivating Use Cases

5.1.  ALTO as part of the SFC eXchange Platform

   As mentioned earlier, the draft [DRAFT-HH-MDSFC] defines a multi-
   domain SFC architecture that combines control planes to be deployed
   either into a large domain consisting of smaller sub-domains owned by
   the same organization or into multiple large domains with different
   ownership.  Figure 1 shows a SXP connecting three different domains
   (AS1, AS2, AS3).  Each domain provides different SFs: AS1 -> SF1; AS2
   -> SF2 and SF3; AS3 -> SF3.  The SXP includes an ALTO server
   component to provide abstract topology, resource, and service
   information for the high-level control plane in each domain.
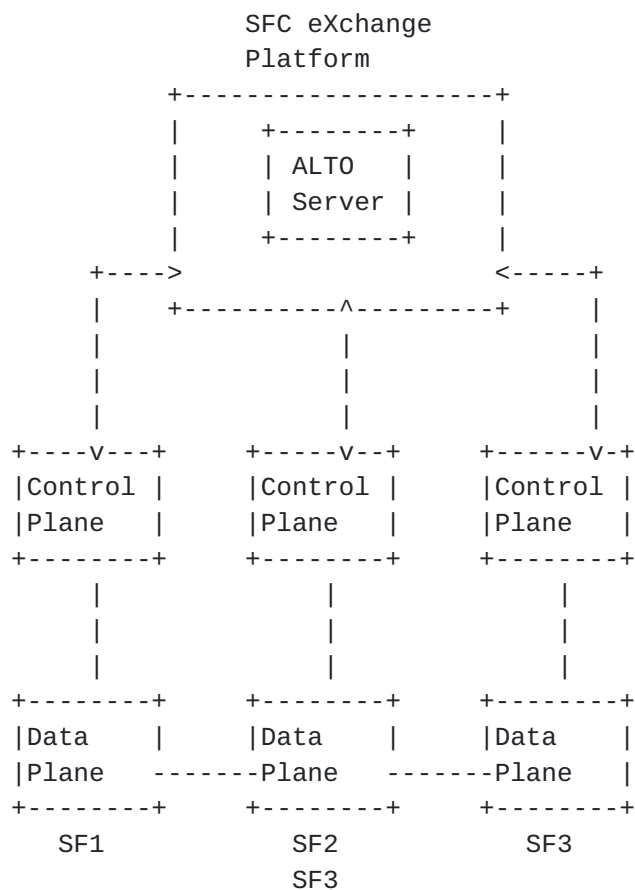
```
                        SFC eXchange
                        Platform
                  +--------------------+
                  |      +--------+     |
                  |      | ALTO   |     |
                  |      | Server |     |
                  |      +--------+     |
             +---->                      <-----+
                  |   +---------^---------+     |
                  |   |         |         |     |
                  |   |         |         |     |
                  |   |         |         |     |
             +----v---+    +-----v--+    +------v-+
             |Control |    |Control |    |Control |
             |Plane   |    |Plane   |    |Plane   |
             +--------+    +--------+    +--------+
                  |            |             |
                  |            |             |
                  |            |             |
             +--------+    +--------+    +--------+
             |Data    |    |Data    |    |Data    |
             |Plane   -------Plane   -------Plane   |
             +--------+    +--------+    +--------+
                SF1           SF2           SF3
                              SF3


          [----AS1----][-----AS2-----][-----AS3-----]
```

            Figure 1: ALTO as part of the SFC eXchange Platform

   Every domain has a local Information Base Element; this component can
   be used by the SXP to create hierarchical databases containing inter-
   domain resource and topology information.  This information source is

used by the ALTO server to create two different ALTO Map Services:
(i) Property Map and (ii) Cost Map.

The Property Map includes a property value grouped by Autonomous
System (AS), this value contains the supported network functions.
Additional properties could be considered such as resource
availability (e.g., CPUs, Memory, and Storage), orchestrator entry
points, etc.  An example of the Property Map in our basic scenario
is:

```
+-----+--------------+-------------+-----+-----+---------+-----+
|     | Capabilities | Entry Point | CPU | MEM | Storage | ... |
+-----+--------------+-------------+-----+-----+---------+-----+
| AS1 | {SF1}        | http://...  | ... | ... | ...     | ... |
| AS2 | {SF2, SF3}   | http://...  | ... | ... | ...     | ... |
| AS3 | {SF3}        | http://...  | ... | ... | ...     | ... |
+-----+--------------+-------------+-----+-----+---------+-----+
```

Table 1: ALTO Property Map

The Cost Map defines a path vector as an array of ASes, representing
the AS-level topological distance for a given SFC request.  Table 2
below shows a brief example of a service request and its inter-domain
service function path response containing a list of potential domains
to be traversed to deliver such service.

```
+--------------+--------------------------------------+
| SFC Request  | Multi-domain Service Function Path(s) |
+--------------+--------------------------------------+
| SF1->SF2->SF3 | 1:{AS1:SF1->AS2:SF2->AS2:SF3}       |
|              | 2:{AS1:SF1->AS2:SF2->AS3:SF3}       |
+--------------+--------------------------------------+
```

Table 2: ALTO Cost Map

## 5.2. Resource Orchestration for Multi-Domain, Geo-Distributed Data Analytics

In addition to commercial SFC, ALTO is also used as a core
information model for collaborative data science networks.  The
document [DRAFT-ALTO-UNICORN] presents the design of Unicorn, a
unified resource orchestration framework for multi-domain, geo-
distributed data analytics, currently being developed and deployed in
the CMS network, one of the largest scientific experiments in the LHC
network.

ALTO is well suited as a fundamental component in Unicorn for
providing a generic representation that (1) allows different types of

data analytics jobs to accurately describe their resource
requirements and (2) allows member networks to provide accurate
information on different types of resources they own and at the same
time maintain their privacies.

```
      .-------------.              .-------------.
      |Application 1|    ...     |Application N|
      '-------------'              '-------------'
             \                         /
.- - - - - - -\- - - - - - - - - - - -/- - - - - - - - - - - - - - -.
|  Unicorn      \                   /                               |
|             .-----------------------.                             |
|             | Resource Orchestrator |   .----------------------.  |
|             |                       |   |Distributed Hash Table||
|             |      .-----------.    |---- |   of Computing and   ||
|             |      |ALTO Client|    |    |   Storage Resources  ||
|             |      '-----------'    |    '----------------------'|
|             '-----------------------'                             |
|         /              |              \                          |
|        /               |               \                         |
|    .-------------.  .-----------.    .-------------.              |
|    |ALTO Server 1|  | Execution |    |ALTO Server M|              |
|    '-------------'  |  Agents   |    '-------------'              |
|         |           '-----------'         |                      |
|         |              /       \          |                      |
|   .----------------./           \ .---------------.               |
|   |     Site 1     |     . .     |     Site N     |               |
|   '----------------'             '---------------'               |
'- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -'
```
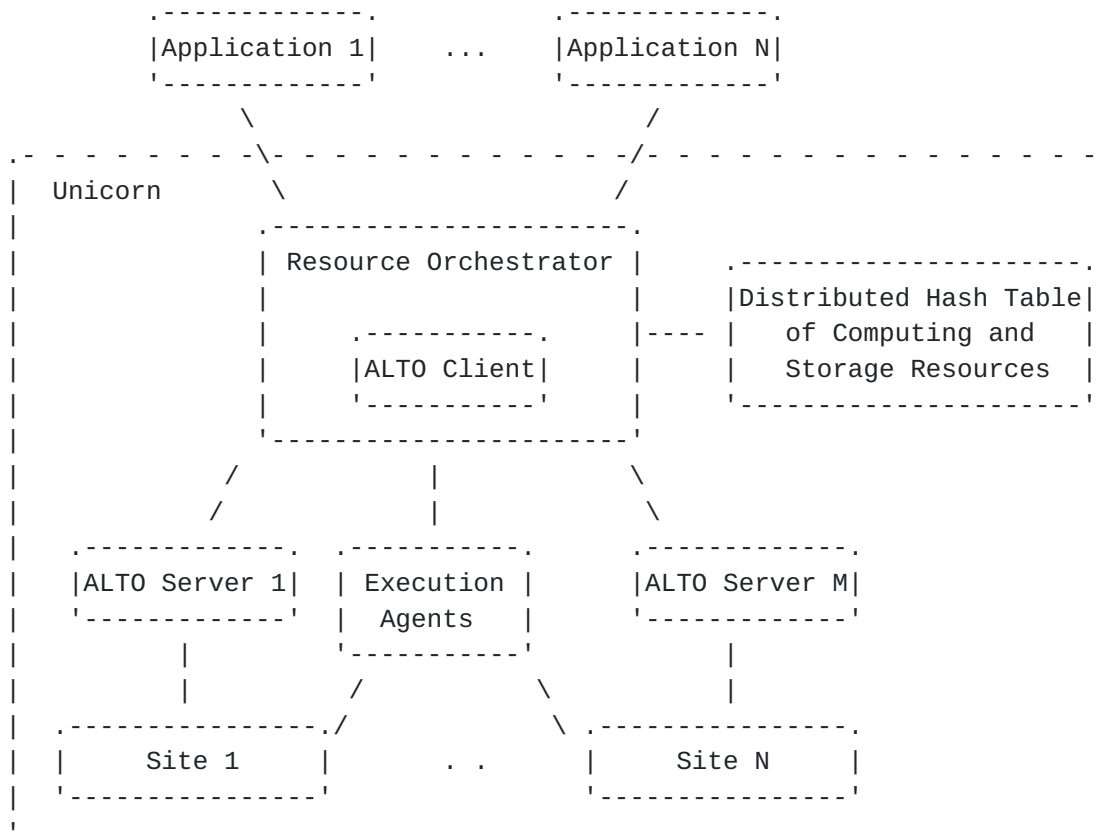
Figure 2: Architecture of Unicorn.

Figure 2 presents the architecture of Unicorn.  Specifically, for
each member network, one or more ALTO servers are deployed to provide
accurate, yet privacy-preserving information of different types of
resources owned by the corresponding network.  Examples of such
information include the link bandwidth between endpoints, the memory
I/O bandwidth and the CPU utilization at computing endpoints and the
storage space at storage endpoints.  In addition to the basic ALTO
services defined in [RFC7285], The ALTO servers in Unicorn also
provide ALTO extension services such as the ALTO Multi-Cost Service
[RFC8189], the ALTO Server-Sent Event Service [DRAFT-ALTO-INCR-UPD]
and the ALTO Path Vector Service [DRAFT-ALTO-PV] to provide fine-
grained resource information.

Because the ALTO Path Vector service may expose additional private
information of each network, Unicorn develops an obfuscating protocol

which ensures that nor the orchestrator or any member networks can
associate any path vector information with a corresponding network.

To better address the scalability issue of multi-domain resource
discovery, Unicorn also develops a proactive full-mesh discovery
mechanism, which precomputes network-level ALTO path vector
information and performs projection using such information to compute
the fine-grained resource information in response to orchestrator's
resource discovery requests.

Details of the obfuscating protocol and the proactive full-mesh
discovery mechanism developed in Unicorn can be found in the
[DRAFT-ALTO-UNICORN] document.

## 6.  IANA Considerations

This document includes no request to IANA.

## 7.  Security Considerations

The ALTO base protocol has an extensive discussion on potential
security and privacy issues.  Using the ALTO base protocol to support
multi-domain SFC will not raise new security and privacy issue.
However, the information provided by the ALTO base protocol is
considered coarse-grained in several recent use cases.  As a result,
several ALTO extension services have been designed to provide fine-
grained network information to the application.  Using these ALTO
extension services for multi-domain SFC would raise new security and
privacy concerns.  Next, we list these issues on a per extension
basis.

The ALTO unified property extension [DRAFT-ALTO-PM] generalizes the
concept of endpoint properties to other entity domains, such as
abstract network element.  The properties of these entities may
contain sensitive service-function-specific information.  Exposing
such information may discourage networks to provide fine-grained
information to support multi-domain SFC.

The ALTO performance cost metrics extension [DRAFT-ALTO-METRICS]
proposes a set of ALTO cost metrics derived from traffic engineering
tools and protocols.  It is stated in this extension that "sharing
network TE metric values in numerical mode requires full mutual
confidence between the entities managing the ALTO Server and Client."
In multi-domain SFC use case, such mutual confidence is needed not
only between ALTO server and client, but also among all networks, and
third-parties such as broker and a global orchestrator.  How to
achieve such mutual confidence in multi-domain SFC use case requires
further investigation.

The ALTO path vector extension [DRAFT-ALTO-PV] allows ALTO clients to query network information such as capacity region for a given set of flows.  Several related studies have shared concerns that this extension may reveal more network internal structures than the more abstract single-node abstraction used in the ALTO base protocol.  In multi-domain SFC, this concern will further be amplified as third-party participants may access such information.  The recent designed Unicorn system proposes an obfuscating protocol that prevents the receiver of the capacity region information from associating this region to any network.  This protocol sheds light for addressing the privacy issue brought by the ALTO path vector extension.

The ALTO cost calendar [DRAFT-ALTO-CALENDAR] and the ALTO incremental update [DRAFT-ALTO-INCR-UPD] extensions allow the ALTO client to get temporal network information.  The intention of these extensions is to allow applications to make flexible decisions on when to use network information.  However, both extensions expose temporal policy and traffic information of network so that a user may know when the network is most vulnerable for overloading.  This issue needs to be carefully addressed in order for both extensions to be used for multi-domain SFC.

## 8.  Summary and Outlook

This draft provided arguments why ALTO is a meaningful protocol in the context of SFC traversing different domains, and it presented use case examples about the how ALTO can be used to advertise and discover abstract topology, resource and service information from different domains, and then compute inter-domain service function paths.

The overall objective of this document is to arouse discussions in the SFC WG in order to assess the suitability of the ALTO as a useful protocol for multi-domain SFC scenarios.  The result of such discussions will be captured in future versions of this draft.

## 9.  Acknowledgments

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