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ALTO Performance Cost Metrics
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Abstract

   Cost metric is a basic concept in Application-Layer Traffic
   Optimization (ALTO), and is used in basic ALTO services including
   both the cost map service and the endpoint cost service.

   Different applications may use different cost metrics, but the ALTO
   base protocol [RFC7285] documents only one single cost metric, i.e.,
   the generic "routingcost" metric; see Sec. 14.2 of [RFC7285]. Hence,
   if the resource consumer of an application prefers a resource
   provider that offers low-delay delivery to the resource consumer, the
   base protocol does not define the cost metric to be used.

   ALTO cost metrics can be generic metrics and this document focuses on
   network performance metrics, including network delay, jitter, packet
   loss, hop count, and bandwidth.

   When using an ALTO performance metric, an application may need
   additional contextual information beyond the metric value. For
   example, whether the metric is an estimation based on measurements or
   a service-level agreement (SLA) can define the meaning of a
   performance metric. Hence, this document introduces an additional
   "cost-context" field to the ALTO "cost-type" field to convey such
   information. To report an estimated value of a performance metric,
   the ALTO server may derive and aggregate from routing protocols with
   different granularity and scope, such as BGP-LS, OSPF-TE and ISIS-TE,
   or from end-to-end traffic management tools. These metrics may then
   be exposed by an ALTO Server to allow applications to determine
   "where" to connect based on network performance criteria.

   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
[RFC2119].

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1. Introduction

   Cost Metric is a basic concept in Application-Layer Traffic
   Optimization (ALTO). It is used in both the ALTO cost map service
   and the ALTO endpoint cost service, to allow applications to request
   network cost metrics.

   Different applications may use different cost metrics. Hence, the
   ALTO base protocol [RFC7285] introduces an ALTO Cost Metric Registry
   (Section 14.2 of [RFC7285]), as a systematic mechanism to allow
   different metrics to be specified. For example, a delay-sensitive
   application may want to use latency related metrics, and a bandwidth-
   sensitive application may want to use bandwidth related metrics. The
   ALTO base protocol [RFC7285], however, has registered only one single
   cost metric, i.e., the generic "routingcost" metric; no latency or
   bandwidth related metrics are defined.

   This document registers a set of new cost metrics specified in
   Table 1, to support the aforementioned applications, to allow them to
   better determine "where" to connect based on network performance
   criteria. This document follows the guideline (Section 14.2 of
   [RFC7285]) of the ALTO base protocol on registering ALTO cost
   metrics. Hence it specifies the identifier, the intended semantics,
   and the security considerations of each one of the metrics defined in
   Table 1.

```
   +--------------------------+------------+------------+
   | Metric                   | Definition |  Origin    |
   +--------------------------+------------+------------+
   | One Way Delay            | Section 2.1 | [RFC7679]  |
   | Round Trip Delay         | Section 2.2 | [RFC2681]  |
   | Packet Delay Variation   | Section 2.3 | [RFC3393]  |
   | Hop Count                | Section 2.4 | [RFC7285]  |
   | Packet Loss              | Section 2.5 | [RFC7680]  |
   | Throughput               | Section 2.6 | [RFC6349]  |
   | Max Reservable Bandwidth | Section 3.1 | [RFC5305]  |
   | Residue Bandwidth        | Section 3.2 | [RFC7810]  |
   +------------+---------------------------------------+
```
       Table 1. Cost Metrics Defined in this Document.

   The purpose of this document is to ensure proper usage of the metrics
   by ALTO clients. It does not claim novelty of the metrics; see
   Table 1 for the source definition of each metric.

   An ALTO server may provide only a subset of the cost metrics
   described in this document. Hence, all cost metrics defined in this
   document are optional and not all of them need to be exposed to a

given application. For example, those that are subject to privacy
concerns should not be provided to unauthorized ALTO clients.

When an ALTO server supports a cost metric defined in this document,
it MUST announce this metric in its information resource directory
(IRD).

An ALTO server introducing these metrics should also consider
security issues. As a generic security consideration on the
reliability and trust in the exposed metric values, applications
SHOULD rapidly give up using ALTO-based guidance if they detect that
the exposed information does not preserve their performance level or
even degrades it. We discuss security considerations in more details
in Section 6.

Following the ALTO base protocol, this document uses JSON to specify
the value type of each defined metric. See [RFC8259] for JSON data
type specification.

2. Performance Metric Context: cost-context

The semantics of a performance metric depends on the context.
Specifically, this document defines three sources when defining
performance metrics: "estimation", "nominal", and "sla".

Even given the source, precise interpretation of a performance metric
value, if needed, depends on an additional set of measurement and
computation parameters. For example, see Section 3.8 of [RFC7679] on
items which a more complete measurement-based report should include.

To make it possible to specify both the source and the additional
parameters, this document introduces an optional "cost-context" field
to the "cost-type" field defined by the ALTO base protocol
(Section 10.7 of [RFC7285]) as the following:

```
object {
  CostMetric   cost-metric;
  CostMode     cost-mode;
  [CostContext cost-context;]
  [JSONString  description;]
} CostType;

object {
  JSONString    cost-source;
  [JSONValue    parameters;]
} CostContext;
```

The "cost-source" MUST be one of only three values: "estimation",
"nominal", and "sla". If a "cost-type" does not include the optional
"cost-context" field which includes the "cost-source" field, the
application MUST assume that the value of "cost-source" is
"estimation".

An ALTO server may compute "estimation" values by retrieving and/or
aggregating information from routing protocols or other traffic
measurement management tools, with corresponding operational issues.
A potential architecture on estimating these metrics is shown in
Figure 1 below. In Section 5, we discuss in more detail the
operational issues and how a network may address them.

```
   +--------+   +--------+  +--------+
   | Client |   | Client |  | Client |
   +----^---+   +---^----+  +---^----+
        |           |           |
      +-----------|-----------+
           NBI    |ALTO protocol
                  |
                  |
             +--+-----+  retrieval      +---------+
             |  ALTO  |<----------------| Routing |
             | Server |  and aggregation|         |
             |        |<-------------+  | Protocol|
             +--------+              |  +---------+
                                     |
                                     |  +---------+
                                     |  |Management
                                  ---|  |         |
                                     |  | Tool    |
                                     +---------+
```
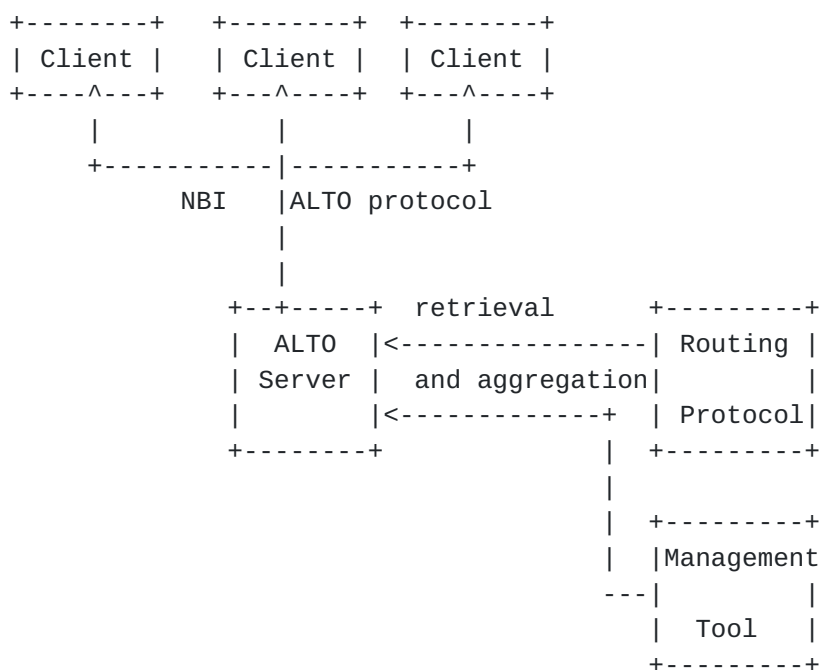
   Figure 1. Potential framework to compute performance cost metrics

3. Network Performance Cost Metrics

   This section introduces generic ALTO network performance metrics such
   as one way delay, round trip delay, hop count, packet loss, and
   throughput.

3.1. Cost Metric: One Way Delay (owdelay)

3.1.1. Identifier

   The identifier for this performance metric is "owdelay".

3.1.2. Value Representation

   The metric value type is a single 'JSONNumber' type value conforming
   to the number specification of [RFC8259] Section 6. The number MUST
   be non-negative. The unit is expressed in milliseconds.

3.1.3. Intended Semantics and Use

   Intended Semantics: To specify spatial and temporal aggregated delay
   of a stream of packets exchanged between the specified source and
   destination or the time that the packet spends to travel from source
   to destination. The spatial aggregation level is specified in the
   query context (e.g., PID to PID, or endpoint to endpoint).

   Use: This metric could be used as a cost metric constraint attribute
   used either together with cost metric attribute 'routingcost' or on
   its own or as a returned cost metric in the response.

Example 1: Delay value on source-destination endpoint pairs

```
POST /endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept:
  application/alto-endpointcost+json,application/alto-error+json

{
  "cost-type": {"cost-mode" : "numerical",
                "cost-metric" : "owdelay"},
  "endpoints" : {
    "srcs": [ "ipv4:192.0.2.2" ],
    "dsts": [
      "ipv4:192.0.2.89",
      "ipv4:198.51.100.34",
      "ipv6:2000::1:2345:6789:abcd"
    ]
  }
}

HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
{
  "meta" :{
    "cost-type": {"cost-mode" : "numerical",
                  "cost-metric" : "owdelay"
     }
   },
    "endpoint-cost-map" : {
      "ipv4:192.0.2.2": {
        "ipv4:192.0.2.89"    : 10,
        "ipv4:198.51.100.34" : 20,
        "ipv6:2000::1:2345:6789:abcd"  : 30,
    }
  }
}
```

Comment: Since the "cost-type" does not include the "cost-source" field, the values are based on "estimation".

3.1.4. Measurement Considerations and Parameters

See Section 4 of [I-D.ietf-ippm-initial-registry] for measurement considerations and parameters which may be specified in "parameters".

Note that the "parameters" field is an optional field providing non-normative information.

3.2. Cost Metric: RoundTrip Time (rtt)

3.2.1. Identifier

The identifier for this performance metric is "rtt".

3.2.2. Value Representation

The metric value type is a single 'JSONNumber' type value conforming to the number specification of [RFC8259] Section 6. The number MUST be non-negative. The unit is expressed in milliseconds.

3.2.3. Intended Semantics and Use

Intended Semantics: To specify spatial and temporal aggregated round trip delay between the specified source and destination or the time that the packet spends to travel from source to destination and then from destination to source. The spatial aggregation level is specified in the query context (e.g., PID to PID, or endpoint to endpoint).

Use: This metric could be used as a cost metric constraint attribute used either together with cost metric attribute 'routingcost' or on its own or as a returned cost metric in the response.

Example 2: Roundtrip Delay value on source-destination endpoint pairs

```
POST /endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept:
  application/alto-endpointcost+json,application/alto-error+json

{
 "cost-type": {"cost-mode" : "numerical",
               "cost-metric" : "rtt"},
  "endpoints" : {
     "srcs": [ "ipv4:192.0.2.2" ],
     "dsts": [
       "ipv4:192.0.2.89",
       "ipv4:198.51.100.34",
       "ipv6:2000::1:2345:6789:abcd"
     ]
   }
}

 HTTP/1.1 200 OK
 Content-Length: TBA
 Content-Type: application/alto-endpointcost+json
 {
   "meta" :{
     "cost-type": {"cost-mode" : "numerical",
                   "cost-metric" : "rtt"
      }
    },
     "endpoint-cost-map" : {
       "ipv4:192.0.2.2": {
         "ipv4:192.0.2.89"    : 4,
         "ipv4:198.51.100.34" : 3,
         "ipv6:2000::1:2345:6789:abcd"  : 2,
     }
    }
  }
```

3.2.4. **Measurement Considerations and Parameters**

See Section 4 of [I-D.ietf-ippm-initial-registry] for measurement
considerations and parameters which may be specified in "parameters".
Note that the "parameters" field is an optional field providing non-
normative information.

3.3. Cost Metric: Packet Delay Variation (pdv)

3.3.1. Identifier

   The identifier for this performance metric is "pdv".

3.3.2. Value Representation

   The metric value type is a single 'JSONNumber' type value conforming
   to the number specification of [RFC8259] Section 6. The number MUST
   be non-negative. The unit is expressed in milliseconds.

3.3.3. Intended Semantics and Use

   Intended Semantics: To specify spatial and temporal aggregated jitter
   (packet delay variation) with respect to the minimum delay observed
   on the stream over the specified source and destination. The spatial
   aggregation level is specified in the query context (e.g., PID to
   PID, or endpoint to endpoint).

   Use: This metric could be used as a cost metric constraint attribute
   used either together with cost metric attribute 'routingcost' or on
   its own or as a returned cost metric in the response.

Example 3: PDV value on source-destination endpoint pairs

```
POST /endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept:
   application/alto-endpointcost+json,application/alto-error+json

{
  "cost-type": {"cost-mode" : "numerical",
   "cost-metric" : "pdv"},
  "endpoints" : {
    "srcs": [ "ipv4:192.0.2.2" ],
    "dsts": [
      "ipv4:192.0.2.89",
      "ipv4:198.51.100.34",
      "ipv6:2000::1:2345:6789:abcd"
    ]
  }
}
HTTP/1.1 200 OK
 Content-Length: TBA
 Content-Type: application/alto-endpointcost+json
{
  "meta": {
          "cost type": {
          "cost-mode": "numerical",
          "cost-metric":"delayjitter"
   }
  },
  "endpoint-cost-map": {
          "ipv4:192.0.2.2": {
          "ipv4:192.0.2.89"    : 0
          "ipv4:198.51.100.34" : 1
          "ipv6:2000::1:2345:6789:abcd"  : 5
       }
     }
   }
```

3.3.4. Measurement Considerations and Parameters

See Section 5 of [I-D.ietf-ippm-initial-registry] for measurement
considerations and parameters which may be specified in "parameters".
Note that the "parameters" field is an optional field providing non-
normative information.

3.4. Cost Metric: Hop Count

The metric hopcount is mentioned in [RFC7285] Section 9.2.3 as an
example. This section further clarifies its properties.

3.4.1. Identifier

The identifier for this performance metric is "hopcount".

3.4.2. Value Representation

The metric value type is a single 'JSONNumber' type value conforming
to the number specification of [RFC8259] Section 6. The number MUST
be an integer and non-negative. The value represents the number of
hops.

3.4.3. Intended Semantics and Use

Intended Semantics: To specify the number of hops in the path between
the source endpoint and the destination endpoint. The hop count is a
basic measurement of distance in a network and can be exposed as
Router Hops, in direct relation to the routing protocols originating
this information.

Use: This metric could be used as a cost metric constraint attribute
used either together with cost metric attribute 'routingcost' or on
its own or as a returned cost metric in the response.

   Example 4: hopcount value on source-destination endpoint pairs

   POST /endpointcost/lookup HTTP/1.1
   Host: alto.example.com
   Content-Length: TBA
   Content-Type: application/alto-endpointcostparams+json
   Accept:
     application/alto-endpointcost+json,application/alto-error+json

   {
     "cost-type": {"cost-mode" : "numerical",
      "cost-metric" : "hopcount"},
     "endpoints" : {
       "srcs": ["ipv4:192.0.2.2"],
       "dsts": [
         "ipv4:192.0.2.89",
         "ipv4:198.51.100.34",
         "ipv6:2000::1:2345:6789:abcd"
       ]
     }
   }

   HTTP/1.1 200 OK
   Content-Length: TBA
   Content-Type: application/alto-endpointcost+json
   {
     "meta": {
               "cost type": {
             "cost-mode": "numerical",
             "cost-metric":"hopcount"}
        }
      },
     "endpoint-cost-map": {
            "ipv4:192.0.2.2": {
            "ipv4:192.0.2.89"   : 5,
            "ipv4:198.51.100.34": 3,
            "ipv6:2000::1:2345:6789:abcd" : 2,
                        }
              }
   }

3.4.4. **Measurement Considerations and Parameters**

   The hop count can be calculated based on the number of routers from
   the source endpoint through which data must pass to reach the
   destination endpoint. This count can be measured at the source
   endpoint by traceroute.

Upon need, the traceroute can use UDP probe message or other
implementations that use ICMP and TCP to discover the hop counts
along the path from source endpoint to destination endpoint.

3.5. Cost Metric: Packet Loss

3.5.1. Identifier

The identifier for this performance metric is "pktloss".

3.5.2. Value Representation

The metric value type is a single 'JSONNumber' type value conforming
to the number specification of [RFC8259] Section 6. The number MUST
be non-negative. The value represents the percentage of packet loss.

3.5.3. Intended Semantics and Use

Intended Semantics: To specify spatial and temporal aggregated packet
loss over the specified source and destination. The spatial
aggregation level is specified in the query context (e.g., PID to
PID, or endpoint to endpoint).

Use: This metric could be used as a cost metric constraint attribute
used either together with cost metric attribute 'routingcost' or on
its own or as a returned cost metric in the response.

Example 5: pktloss value on source-destination endpoint pairs

```
POST /endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept:
  application/alto-endpointcost+json,application/alto-error+json

  {
    "cost-type": {"cost-mode" : "numerical",
     "cost-metric" : "pktloss"},
    "endpoints" : {
      "srcs": [ "ipv4:192.0.2.2" ],
      "dsts": [
        "ipv4:192.0.2.89",
        "ipv4:198.51.100.34",
        "ipv6:2000::1:2345:6789:abcd"
      ]
    }
  }
```

```
HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
{
    "meta": {
              "cost type": {
             "cost-mode": "numerical",
             "cost-metric":"pktloss"}
        }
    },
    "endpoint-cost-map": {
            "ipv4:192.0.2.2": {
            "ipv4:192.0.2.89"   : 0,
            "ipv4:198.51.100.34": 0,
            "ipv6:2000::1:2345:6789:abcd" : 0,
                           }
              }
 }
```

3.5.4. Measurement Considerations and Parameters

See [Section 4](#) of [I-D.ietf-ippm-initial-registry] for measurement
considerations and parameters which may be specified in "parameters".
Note that the "parameters" field is an optional field providing non-
normative information.

3.6. Cost Metric: Throughput

3.6.1. Identifier

The identifier for this performance metric is "throughput".

3.6.2. Value Representation

The metric value type is a single 'JSONNumber' type value conforming
to the number specification of [RFC8259] Section 6. The number MUST
be non-negative. The unit is Mbps.

3.6.3. Intended Semantics and Use

Intended Semantics: To specify spatial and temporal throughput over
the specified source and destination. The spatial aggregation level
is specified in the query context (e.g., PID to PID, or endpoint to
endpoint).

Use: This metric could be used as a cost metric constraint attribute
used either together with cost metric attribute 'routingcost' or on
its own or as a returned cost metric in the response.

   Example 5: throughtput value on source-destination endpoint pairs

   POST /endpointcost/lookup HTTP/1.1
   Host: alto.example.com
   Content-Length: TBA
   Content-Type: application/alto-endpointcostparams+json
   Accept:
     application/alto-endpointcost+json,application/alto-error+json

   {
     "cost-type": {"cost-mode" : "numerical",
                   "cost-metric" : "throughput"},
     "endpoints" : {
       "srcs": ["ipv4:192.0.2.2"],
       "dsts": [
          "ipv4:192.0.2.89",
          "ipv4:198.51.100.34",
          "ipv6:2000::1:2345:6789:abcd"
       ]
     }
   }

   HTTP/1.1 200 OK
   Content-Length: TBA
   Content-Type: application/alto-endpointcost+json
   {
     "meta": {
        "cost type": {
           "cost-mode": "numerical",
           "cost-metric":"throughput"
       }
     }
     "endpoint-cost-map": {
       "ipv4:192.0.2.2": {
         "ipv4:192.0.2.89"   : 25.6,
         "ipv4:198.51.100.34": 12.8,
         "ipv6:2000::1:2345:6789:abcd" : 42.8,
     }
   }

3.6.4. Measurement Considerations and Parameters

   See Section 3.3 of [RFC6349] for measurement method and parameters
   which may be specified in "parameters". Note that the "parameters"
   field is an optional field providing non-normative information.

4. Traffic Engineering Performance Cost Metrics

This section introduces ALTO network performance metrics that may be aggregated from network metrics measured on links and specified in other documents. In particular, the bandwidth related metrics specified in this section are only available through link level measurements. For some of these metrics, the ALTO Server may further expose aggregated values while specifying the aggregation laws.

4.1. Cost Metric: Link Maximum Reservable Bandwidth

4.1.1. Identifier

The identifier for this performance metric is "maxresbw".

4.1.2. Value Representation

The metric value type is a single 'JSONNumber' type value that is non-negative. The unit of measurement is Mbps.

4.1.3. Intended Semantics and Use

Intended Semantics: To specify spatial and temporal maximum reservable bandwidth over the specified source and destination. The value is corresponding to the maximum bandwidth that can be reserved (motivated from RFC 3630 Sec. 2.5.7.). The spatial aggregation unit is specified in the query context (e.g., PID to PID, or endpoint to endpoint).

Use: This metric could be used as a cost metric constraint attribute used either together with cost metric attribute 'routingcost' or on its own or as a returned cost metric in the response.

Example 6: maxresbw value on source-destination endpoint pairs

```
POST/ endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept:
  application/alto-endpointcost+json,application/alto-error+json

  {
    "cost-type" { "cost-mode":  "numerical",
                  "cost-metric":  "maxresbw"},
    "endpoints":  {
      "srcs": [ "ipv4 : 192.0.2.2" ],
      "dsts": [
        "ipv4:192.0.2.89",
        "ipv4:198.51.100.34",
        "ipv6:2000::1:2345:6789:abcd"
      ]
    }
  }

HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
{
    "meta": {
          "cost-type": {
          "cost-mode": "numerical",
          "cost-metric": "maxresbw"
          }
    },
  " endpoint-cost-map": {
          "ipv4:192.0.2.2" {
          "ipv4:192.0.2.89" :     0,
          "ipv4:198.51.100.34": 2000,
          "ipv6:2000::1:2345:6789:abcd":  5000,
                      }
          }
}
```

4.1.4. Measurement Considerations and Parameters

Method of Measurement or Calculation:

Maximum Reservable Bandwidth is the bandwidth measured between two
directly connected IS-IS neighbors or OSPF neighbors. See
Section 3.5 of [RFC5305] for Measurement Method.

Measurement Point(s) with Potential Measurement Domain:

See Section 4.1 this document for discussions.

Measurement Timing:

See Section 3.5 of [RFC5305] and Section 5 of [RFC7810] for
Measurement Timing.

4.2. Cost Metric: Link Residue Bandwidth

4.2.1. Identifier

The identifier for this performance metric is "residuebw".

4.2.2. Value Representation

The metric value type is a single 'JSONNumber' type value that is
non-negative. The unit of measurement is Mbps.

4.2.3. Intended Semantics and Use

Intended Semantics: To specify spatial and temporal residual
bandwidth over the specified source and destination. The value is
calculated by subtracting tunnel reservations from Maximum Bandwidth
(motivated from [RFC7810], Section 4.5.). The spatial aggregation
unit is specified in the query context (e.g., PID to PID, or endpoint
to endpoint).

Use: This metric could be used as a cost metric constraint attribute
used either together with cost metric attribute 'routingcost' or on
its own or as a returned cost metric in the response.

Example 7: residuebw value on source-destination endpoint pairs

```
POST/ endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept:
  application/alto-endpointcost+json,application/alto-error+json

  {
   "cost-type": { "cost-mode":  "numerical",
                  "cost-metric":  "residuebw"},
    "endpoints":  {
      "srcs": [ "ipv4 : 192.0.2.2" ],
      "dsts": [
        "ipv4:192.0.2.89",
        "ipv4:198.51.100.34",
        "ipv6:2000::1:2345:6789:abcd"
     ]
   }
   }
```

```
HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
{
   "meta": {
           "cost-type" {
           "cost-mode": "numerical",
           "cost-metric": "residuebw"
        }
     },
   "endpoint-cost-map" {
           "ipv4:192.0.2.2" {
           "ipv4:192.0.2.89" :     0,
           "ipv4:198.51.100.34": 2000,
           "ipv6:2000::1:2345:6789:abcd":  5000,
                      }
        }
   }
```

4.2.4. Measurement Considerations and Parameters

Method of Measurement or Calculation:

Residue Bandwidth is the Unidirectional Residue bandwidth measured
between two directly connected IS-IS neighbors or OSPF neighbors.
See Section 4.5 of [RFC7810] for Measurement Method.

Measurement Point(s) with Potential Measurement Domain:

> See Section 4.1 of this document.

Measurement Timing:

> See Section 5 of [RFC7810] for Measurement Timing.

5. Operational Considerations

The exact measurement infrastructure, measurement condition and
computation algorithms can vary from different networks, and are
outside the scope of this document. Both the ALTO server and the
ALTO clients, however, need to be cognizant of the operational issues
discussed below.

Also, the performance metrics specified in this document are similar,
in that they may use similar data sources and have similar issues in
their calculation. Hence, we specify common issues unless one metric
has its unique challenges.

5.1. Source Considerations

The addition of the "cost-source" field is to solve a key issue: An
ALTO server needs data sources to compute the cost metrics described
in this document and an ALTO client needs to know the data sources to
better interpret the values.

To avoid too fine-grained information, this document introduces
"cost-source" to indicate only the high-level type of data sources:
"estimation" or "sla", where "estimation" is a type of measurement
data source and "sla" is a type that is more based on policy.

For estimation, for example, the ALTO server may use log servers or
the OAM system as its data source [RFC7971]. In particular, the cost
metrics defined in this document can be computed using routing
systems as the data sources. Mechanisms defined in [RFC2681],
[RFC3393], [RFC7679], [RFC7680], [RFC3630], [RFC3784], [RFC7471],
[RFC7810], [RFC7752] and [I-D.ietf-idr-te-pm-bgp] that allow an ALTO
Server to retrieve and derive the necessary information to compute
the metrics that we describe in this document.

5.2. Backward Compatibility Considerations

   One potential issue introduced by the optional "cost-source" field is
   backward compatibility. Consider that an IRD which defines two cost-
   types with the same "cost-mode" and "cost-metric", but one with
   "cost-source" being "estimation" and the other being "sla". Then an
   ALTO client that is not aware of the extension will not be able to
   distinguish between these two types. A similar issue can arise even
   with a single cost-type which has "cost-source" being "sla", but the
   backward client will ignore this field and consider the metric
   estimation.

   To address this issue, the only defined "routingcost" metric can be
   ONLY "estimation".

5.3. Computation Considerations

   The metric values exposed by an ALTO server may result from
   additional processing on measurements from data sources to compute
   exposed metrics. This may involve data processing tasks such as
   aggregating the results across multiple systems, removing outliers,
   and creating additional statistics. There are two challenges on the
   computation of ALTO performance metrics.

5.3.1. Configuration Parameters Considerations

   Performance metrics often depend on configuration parameters. For
   example, the value of packet loss rate depends on the measurement
   interval and varies over time. To handle this issue, an ALTO server
   may collect data on time periods covering the previous and current
   time or only collect data on present time. The ALTO server may
   further aggregate these data to provide an abstract and unified view
   that can be more useful to applications. To make the ALTO client
   better understand how to use these performance data, the ALTO server
   may provide the client with the validity period of the exposed metric
   values.

5.3.2. Availability Considerations

   Applications value information relating to bandwidth availability
   whereas bandwidth related metrics can often be only measured at the
   link level. This document specifies a set of link-level bandwidth
   related values that may be exposed as such by an ALTO server. The
   server may also expose other metrics derived from their aggregation
   and having different levels of endpoint granularity, e.g., link
   endpoints or session endpoints. The metric specifications may also
   expose the utilized aggregation laws.

6. **Security Considerations**

   The properties defined in this document present no security
   considerations beyond those in Section 15 of the base ALTO
   specification [RFC7285].

   However concerns addressed in Sections "15.1 Authenticity and
   Integrity of ALTO Information", "15.2 Potential Undesirable Guidance
   from Authenticated ALTO Information" and "15.3 Confidentiality of
   ALTO Information" remain of utmost importance. Indeed, TE
   performance is a highly sensitive ISP information, therefore, sharing
   TE metric values in numerical mode requires full mutual confidence
   between the entities managing the ALTO Server and Client. Numerical
   TE performance information will most likely be distributed by ALTO
   Servers to Clients under strict and formal mutual trust agreements.
   On the other hand, ALTO Clients must be cognizant on the risks
   attached to such information that they would have acquired outside
   formal conditions of mutual trust.

7. **IANA Considerations**

   IANA has created and now maintains the "ALTO Cost Metric Registry",
   listed in Section 14.2, Table 3 of [RFC7285]. This registry is
   located at <http://www.iana.org/assignments/alto-protocol/alto-
   protocol.xhtml#cost-metrics>. This document requests to add the
   following entries to "ALTO Cost Metric Registry".

```
   +------------+--------------------+
   | Identifier | Intended Semantics |
   +------------+--------------------+
   | owdelay    | See Section 2.1    |
   | rtt        | See Section 2.2    |
   | pdv        | See Section 2.3    |
   | hopcount   | See Section 2.4    |
   | pktloss    | See Section 2.5    |
   | throughput | See Section 2.6    |
   | maxresbw   | See Section 3.1    |
   | residuebw  | See Section 3.2    |
   +------------+--------------------+
```

   This document requests the creation of the "ALTO Cost Source
   Registry" with the following currently defined values:

```
+------------+---------------------------+
| Identifier | Intended Semantics        |
+------------+---------------------------+
| estimation | Values by estimation      |
| nominal    | Values in nominal cases   |
| sla        | Values reflecting service |
|            | level agreement           |
+------------+---------------------------+
```

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