ALTO Working Group   Q. Wu
Internet-Draft   Huawei
Intended status: Standards Track   Y. Yang
Expires: June 25, 2018   Yale University
                                                                Y. Lee
                                                              D. Dhody
                                                                Huawei
                                                      S. Randriamasy
                                                      Nokia Bell Labs
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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). It is used in both the Cost Map Service and the
   Endpoint Cost Service.

   Different applications may benefit from different Cost Metrics. For
   example, a Resource Consumer may prefer Resource Providers that offer
   a low delay delivery to the Resource Consumer. However the base ALTO
   protocol [ALTO] has documented only one single cost metric, i.e., the
   generic "routingcost" metric (Sec. 14.2 of ALTO base specification
   [ALTO]).

   This document, proposes a set of Cost Metrics, derived and aggregated
   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. It currently documents Network Performance Cost Metrics
   reporting on network delay, jitter, packet loss, hop count, and
   bandwidth. These metrics may be exposed by an ALTO Server to allow
   applications to determine "where" to connect based on network
   performance criteria. Additional Cost Metrics involving ISP specific
   considerations or other network technologies may be documented in
   further versions of this draft.

   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

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1. Introduction

   Cost Metric is a basic concept in Application-Layer Traffic
   Optimization (ALTO). It is used in both the Cost Map Service and the
   Endpoint Cost Service. In particular, applications may benefit from
   knowing network performance measured on several Cost Metrics. For
   example, a more delay-sensitive application may focus on latency, and
   a more bandwidth-sensitive application may focus on available
   bandwidth.

   This document introduces a set of new cost metrics, listed in
   Table 1, to support the aforementioned applications and allow them to
   determine "where" to connect based on network performance criteria.
   Hence, this document extends the base ALTO protocol [ALTO], which
   defines only a single cost metric, i.e., the generic "routingcost"
   metric (Sec. 14.2 of ALTO base specification [ALTO]).

```
+----------+--------------+--------------------------------------------+
|Namespace | Property     | Reference                                  |
+----------+--------------+--------------------------------------------+
|          |     owdelay  | See Section 3,[RFC2679] Section 3.6        |
|          |      rtt     | See Section 4,[RFC2681] Section 2.6        |
|          |      pdv     | See Section 5,[RFC3393] Section 2.6        |
|          | hopcount     | See Section 6,[RFC7285]                    |
|          | pktloss      | See Section 7,[RFC7680] Section 2.6        |
|          | maxresbw     | See Section 8.1,[RFC5305] Section 3.5      |
|          | residbw      | See Section 8.2,[RFC7810] Section 4.5      |
|          | availbw      | See Section 8.3,[RFC7810] Section 4.6      |
|          | utilbw       | See Section 8.4,[RFC7810] Section 4.7       |
+----------+--------------+--------------------------------------------+
                    Table 1.
```

   The purpose of this draft is to list the metrics likely to be exposed
   to ALTO Clients, including those already specified in other
   standardization groups and as such it does not claim novelty on all
   the specified metrics. Some metrics may have values produced by
   standard measurement methods such as those specified in IPPM, some

may be ISP dependent such as those registered in ISIS or OSPF-TE. In
this case, this document will refer to the relevant specifications.

An ALTO server may provide a subset of the cost metrics described in
this document. These cost metrics can be retrieved and aggregated
from routing protocols or other traffic measurement management tools
(See Figure 1). Note that these cost metrics are optional and not
all them need to be exposed to applications. For example, those that
are subject to privacy concerns should not be provided to
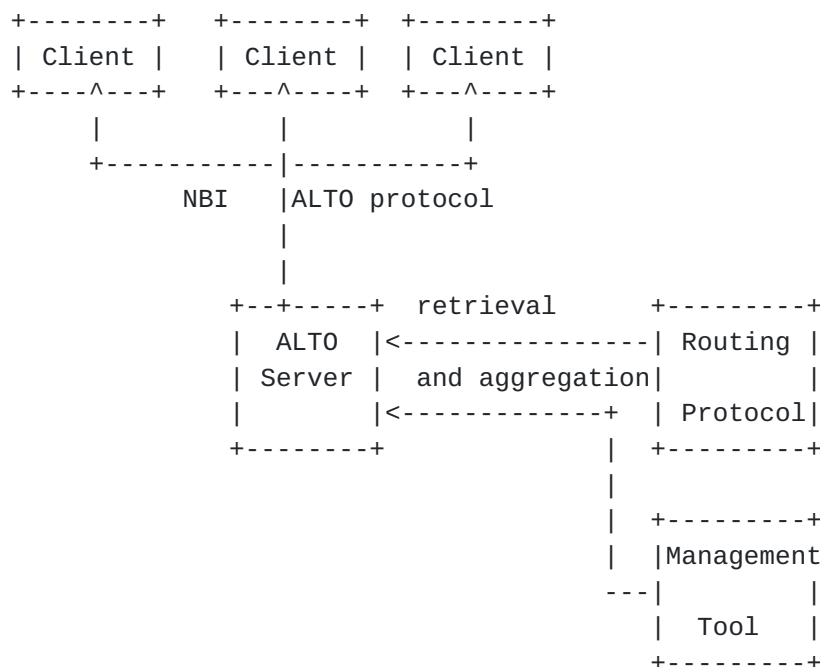unauthorized ALTO clients.

```
+--------+   +--------+  +--------+
| Client |   | Client |  | Client |
+----^---+   +---^----+  +---^----+
     |           |           |
     +-----------|-----------+
          NBI    |ALTO protocol
                 |
                 |
             +--+-----+  retrieval      +---------+
             |   ALTO |<----------------| Routing |
             | Server |  and aggregation|         |
             |        |<-------------+  | Protocol|
             +--------+              |  +---------+
                                     |
                                     |  +---------+
                                     |  |Management
                                  ---|  |         |
                                     |  |  Tool   |
                                     |  +---------+
```

                 Figure 1.End-to-End Path Cost Metrics Exposing

   When an ALTO server supports a cost metric defined in this document,
   it MUST announce this metric in its IRD.

   Additionally, future versions of this document may define network
   metric values that stem from both measurements and provider policies
   such as many metrics related to end-to-end path bandwidth.

   As for the reliability and trust in the exposed metric values,
   applications SHOULD rapidly give up using ALTO-based guidance if they
   feel the exposed information does not preserve their performance
   level or even degrades it.

   Following the ALTO base protocol, this document uses JSON to specify
   the value type of each defined metric. See [RFC4627] for JSON data
   type specification.

2. Challenges on data sources and computation of ALTO performance metrics

2.1. Data sources Challenge

An ALTO server needs data sources to compute the cost metrics described in this document. This document does not define the exact data sources. For example, the ALTO server may use log servers or the OAM system as its data source [ALTO-DEPLOYMENT]. In particular, the cost metrics defined in this document can be computed using routing systems as the data sources. Mechanisms defined in [RFC3630], [RFC3784], [OSPF-TE], [ISIS-TE], [BGP-LS] and [BGP-PM] that allow an ALTO Server to retrieve and derive the necessary information to compute the metrics that we describe in this document.

One challenge lies in the data sources originating the ALTO metric values. The very important purpose of ALTO is to guide application traffic with provider network centric information that may be exposed to ALTO Clients in the form of network performance metric values. Not all of these metrics have values produced by standardized measurement methods or routing protocols. Some of them involve provider-centric policy considerations. Some of them may describe wireless or cellular networks. To reliably guide users and applications while preserving provider privacy, ALTO performance metric values may also add abstraction to measurements or provide unitless performance scores.

2.2. ALTO performance metrics Computation Challenges

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 computation of ALTO performance metrics.

2.2.1. Configuration Parameters Challenge

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.

2.2.2. Availability of end to end path values Challenge

Applications value information relating to bandwidth availability where as 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.

3. Cost Metric: POWDelay

Metric name:

> Periodic One Way Delay

Metric Description:

> 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).

Method of Measurement or Calculation:

> See section 8.3 of [I-D.ietf-ippm-initial-registry] for Measurement Method.

Units of Measurement:

> See section 8.4.3 of [I-D.ietf-ippm-initial-registry] for Measurement Unit. The unit is expressed in seconds.

Measurement Point(s) with Potential Measurement Domain:

> See section 2.1, Data sources.

Measurement Timing:

> See section 8.3.5 of [I-D.ietf-ippm-initial-registry] for Measurement Timing.

Use and Applications:

The Metric value Type is a single 'JSONNumber' type value
containing a non-negative integer component that may be followed
by an exponent part. The Cost Mode is encoded as a US-ASCII
string.

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" : "powdelay"},
  "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" : "powdelay"
     }
   },
    "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,
    }
  }
}
```

4. Cost Metric: RTT

Metric name:

   Round Trip Delay

Metric Description:

   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).

Method of Measurement or Calculation:

   See section 4.3 of [I-D.ietf-ippm-initial-registry] for
   Measurement Method.

Units of Measurement:

   See section 4.4.3 of [I-D.ietf-ippm-initial-registry] for
   Measurement Unit. The unit is expressed in seconds.

Measurement Point(s) with Potential Measurement Domain:

      See [section 2.1](#), Data sources.

   Measurement Timing:

      See section 4.3.5 of [[I-D.ietf-ippm-initial-registry](#)] for
      Measurement Timing.

   Use and Applications:

      See [section 3](#) for use and application.

 Example 2: Round Trip 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,
      }
    }
   }
```


[5](#). Cost Metric: PDV

Metric name:

   Packet Delay Variation

Metric Description:

   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).

Method of Measurement or Calculation:

   See section 5.3 of [I-D.ietf-ippm-initial-registry] for
   Measurement Method.

Units of Measurement:

   See section 5.4.4 of [I-D.ietf-ippm-initial-registry] for
   Measurement Unit. The unit is expressed in seconds.

Measurement Point(s) with Potential Measurement Domain:

See section 2.1, Data sources.

   Measurement Timing:

      See section 5.3.5 of [I-D.ietf-ippm-initial-registry] for
      Measurement Timing.

   Use and Applications:

      See section 3 for use and application.

   Example 3: Delay jitter 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" : "delayjitter"},
     "endpoints" : {
       "srcs": ["ipv4:192.0.2.2"],
       "dsts": [
         "ipv4:192.0.2.89",
         "ipv4:198.51.100.34",
         "ipv6:2000::1:2345:6789:abcd"
       ]
     }
   }

   Example 3: Delay jitter 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" : "delayjitter"},
     "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
           }
         }
       }

6. Cost Metric: Hop Count

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

   Metric name:

      Hop count

Metric Description:

   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, IP hops or other hops in direct relation to the routing
   protocols originating this information. It might also result from
   the aggregation of such information.

Method of Measurement or Calculation:

   See section 2.2, Computation of metrics.

Units of Measurement:

   The unit is integer number.

Measurement Point(s) with Potential Measurement Domain:

   See section 2.1, Data sources.

Measurement Timing:

   See section 2.1, second paragraph for Measurement Timing.

Use and Applications:

   See section 3 for use and application.

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,
                         }
             }
  }
```

7. Cost Metric: Packet Loss

   Metric name:

      Packet loss

   Metric Description:

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).

Method of Measurement or Calculation:

See section 2.6 of [RFC7680] for Measurement Method.

Units of Measurement:

The unit is percentile.

Measurement Point(s) with Potential Measurement Domain:

See section 2.1, Data sources.

Measurement Timing:

See section 2 and section3 of [RFC7680] for Measurement Timing.

Use and Applications:

See section 3 for use and application.

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": 1,
           "ipv6:2000::1:2345:6789:abcd" : 2,
                       }
             }
  }
```

8. 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.

8.1. Cost Metric: Link Maximum Reservable Bandwidth

   Metric name:

      Maximum Reservable Bandwidth

   Metric Description:

      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).

   Method of Measurement or Calculation:

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

   Units of Measurement:

      The unit of measurement is byte per seconds.

   Measurement Point(s) with Potential Measurement Domain:

      See section 2.1, Data sources.

   Measurement Timing:

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

   Use and Applications:

      See section 3 for use and application.

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,
                         }
             }
 }
```

8.2. Cost Metric: Link Residue Bandwidth

Metric name:

   Residue Bandwidth

Metric Description:

   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], Sec.4.5.). The spatial aggregation unit is
   specified in the query context (e.g., PID to PID, or endpoint to
   endpoint).

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.

Units of Measurement:

   The unit of measurement is byte per seconds.

Measurement Point(s) with Potential Measurement Domain:

   See section 2.1, Data sources.

Measurement Timing:

   See section 5 of [RFC7810] for Measurement Timing.

Use and Applications:

   See section 3 for use and application.

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":  "residubw"},
    "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": "residubw"
         }
      },
   "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,
                      }
         }
    }
```

8.3. Cost Metric: Link Available Bandwidth

Metric name:

   Available Bandwidth

Metric Description:

To specify spatial and temporal availaible bandwidth over the
specified source and destination. The value is calculated by
subtracting the measured bandwidth used for the actual forwarding
of best effort traffic from Residue Bandwidth (motivated from
[RFC7810], Sec.4.6.). The spatial aggregation level is specified
in the query context (e.g., PID to PID, or endpoint to endpoint).

Method of Measurement or Calculation:

Available bandwidth is the Unidirectional Available bandwidth
measured between two directly connected IS-IS neighbors or OSPF
neighbors, See section 4.6 of [RFC7810] for Measurement Method.

Units of Measurement:

The unit of measurement is byte per seconds.

Measurement Point(s) with Potential Measurement Domain:

See section 2.1, Data sources.

Measurement Timing:

See section 5 of [RFC7810] for Measurement Timing.

Use and Applications:

See section 3 for use and application. Besides, knowledge about
available bandwidth is essential for applications to distribute or
schedule their transmissions. The example below illustrates how
this metric is provided in the form of an ALTO calendar, as
specified in [XXXX] to help deciding "where" and "when" to
transmit.

Example 8: availbw value on source-destination endpoint pairs

This example assumes that the ALTO Server provides the values for
metric "availbw" in the form of an ALTO calendar and declares it
in its IRD.

```
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":  "availbw"},
   "calendared" : [true],
   "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": "availbw"
         }
         "calendar-response-attributes" : [
            "calendar-start-time" : Tue, 1 Mar 2017 13:00:00 GMT,
            "time-interval-size" : "1 hour",
            "numb-intervals" : 8
       ]
    },

    "endpoint-cost-map": {
         "ipv4:192.0.2.2" {
         "ipv4:192.0.2.89" : [6,5,7,8,4,10,7,6],
         "ipv4:198.51.100.34" : [7,4,6,8,5,9,6,7],
         "ipv6:2000::1:2345:6789:abcd" : [7,6,8,5,7,9,6,8],
         }
       }
}
```

8.4. Cost Metric: Link Utilized Bandwidth

Metric name:

   Utilized Bandwidth

Metric Description:

   To specify spatial and temporal utilized bandwidth over the
   specified source and destination. The value is corresponding to
   the actual measured bandwidth used for all traffic (motivated from
   [RFC7810], Sec.4.7.). The spatial aggregation level is specified
   in the query context (e.g., PID to PID, or endpoint to endpoint).

Method of Measurement or Calculation:

   Link Utilizated bandwidth is Unidirectional utilization bandwidth
   measured between two directly connected IS-IS neighbors or OSPF
   neighbors, See section 4.7 of [RFC7810] for Measurement Method.

Units of Measurement:

The unit of measurement is byte per seconds.

Measurement Point(s) with Potential Measurement Domain:

See section 2.1, Data sources.

Measurement Timing:

Link Utilized bandwidth is Unidirectional utilization bandwidth
measured between two directly connected IS-IS neighbors or OSPF
neighbors, See section 5 of [RFC7810] for Measurement Timing.

Use and Applications:

See section 3 for use and application.

Example 9: utilbw 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" :  "utilbw"},
  "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": "utilbw"
           }
     },
   "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,
                           }
           }
   }
```

9. Security Considerations

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

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.

10. 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 Meric Registry".

```
+----------+-------------+--------------------------------------------+
|Namespace | Property    | Reference                                  |
+----------+-------------+--------------------------------------------+
|          |   owdelay   | [thisdraft] Section 3,[RFC2679] Section 3.6 |
|          |    rtt      | [thisdraft] Section 4,[RFC2681],Section 2.6 |
|          |    pdv      | [thisdraft] Section 5,[RFC3393],Section 2.6 |
|          | hopcount    | [thisdraft] Section 6,[RFC7285]            |
|          | pktloss     | [thisdraft] Section 7,[RFC7680],Section 2.6 |
|          | maxresbw    | [thisdraft] Section 8.1,[RFC5305],Section 3.5|
|          | residbw     | [thisdraft] Section 8.2,[RFC7810],Section 4.5|
|          | availbw     | [thisdraft] Section 8.3,[RFC7810],Section 4.6|
|          | utilbw      | [thisdraft] Section 8.4,[RFC7810,Section4.7] |
+----------+-------------+--------------------------------------------+
```

11. References

11.1. Normative References

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Appendix A. Open Issue List

   We need to consider to add Cellular endpoint format support in the
   example, the Cellular endpoint format is specified in draft-
   randriamasy-alto-cellular-adresses.

Authors' Addresses

   Qin Wu
   Huawei
   101 Software Avenue, Yuhua District
   Nanjing, Jiangsu 210012
   China

   Email: bill.wu@huawei.com

   Y. Richard Yang
   Yale University
   51 Prospect St
   New Haven, CT 06520
   USA

   Email: yry@cs.yale.edu

   Young Lee
   Huawei
   1700 Alma Drive, Suite 500
   Plano, TX 75075
   USA

   Email: leeyoung@huawei.com

   Dhruv Dhody
   Huawei
   Leela Palace
   Bangalore, Karnataka 560008
   INDIA

   Email: dhruv.ietf@gmail.com

Sabine Randriamasy
Nokia Bell Labs
Route de Villejust
Nozay 91460
FRANCE

Email: sabine.randriamasy@nokia-bell-labs.com