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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. Future extensions to ALTO may also use Cost Metric.

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

In this document, we 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 tool. We currently document 11 new Performance Metric to measure network delay, jitter, packet loss, hop count, and bandwidth. The metrics documented in this document provide a relatively comprehensive set of Cost Metrics for ALTO and allow applications to determine "where" to connect based on end to end network performance criteria. Additional Cost Metrics such as financial cost metrics may be documented in other documents.

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.

The objective of this document is to introduce 11 new performance cost metrics, listed in Table 1, to support the aforementioned applications and allow applications to determine "where" to connect based on end to end 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	[RFCxxxx], Section 3
	pdv	[RFCxxxx], Section 4
	pktloss	[RFCxxxx], Section 5
	hopcount	[RFCxxxx], Section 6
	bandwidth	[RFCxxxx], Section 7
	maxbw	[RFCxxxx], Section 8
	maxresbw	[RFCxxxx], Section 9
	rtt	[RFCxxxx], Section 10
	residbw	[RFCxxxx], Section 11
	availbw	[RFCxxxx], Section 12
	utilbw	[RFCxxxx], Section 13

Table 1.

An ALTO server may provide a subset of the cost metrics documented in this document. These cost metrics can be retrieved and aggregated from routing protocol or other traffic measurement management tool (See Figure 1). Note that these cost metrics are optional metrics and Not all these cost metrics need to be exposed to the application.

If some of these cost metrics have privacy concern, the alto server should not provide them to the client.

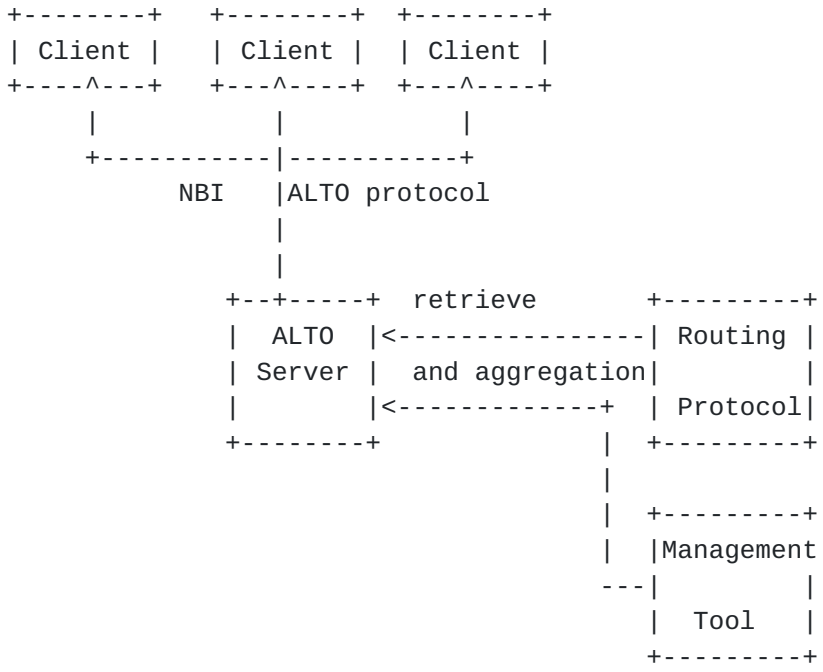

Figure 1.End to End Path Cost Metrics Exposing

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

The definitions of a set of cost metrics can allow us to extend the ALTO base protocol (e.g., allowing output and constraints use different cost metrics), but such extensions are not in the scope of this document.

One challenge in describing the metrics is that 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, ALTO server may collect data on time periods covering the past, present or only collect data on present time. The ALTO may further aggregate these data to provide an abstract and unified view that can be more useful to applications. To make the ALTO client understand whether the performance data is past data or present data, the ALTO server needs to expose to the client the validity period of each performance metric.

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. Data sources, computation of defined cost metrics

The cost metrics described in this document are similar, in that they may use similar data sources and have similar issues in their calculation. Hence, instead of specifying such issues for each metric individually, we specify the common issue in this section.

2.1. Data sources

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 described in this document.

2.2. Computation of metrics

An ALTO server processes measurements from data sources to compute exposed metrics. It may need performance data processing tasks such as aggregating the results across multiple systems, removing outliers, and creating additional statistics.

One specific challenge in deriving the metrics in this document is that these performance metrics depend on some configuration parameters. For example, the value of packet loss rate depends on the measurement interval and varies over time. If the ALTO server uses aforementioned routing protocol based mechanisms as data sources, then the measurement interval may be preconfigured by the routing protocol. For example, Section 5 of [ISIS-TE] defines a default measurement interval of 30 seconds. This document uses the term Measurement Interval to refer to the measurement interval used by the data sources. In the [ISIS-TE] case, it is a measurement interval set by routing protocol. The Measurement Interval(s) of the data sources can be different from the interval that this document derives the metric, e.g., the interval used by this document is multiple of measurement interval of the data sources. Hence, an ALTO server needs to resolve the mismatch, when it happens.

Another issue of converting from data source measurements to ALTO exposed metric values is that the measurement results that the ALTO Server retrieves may be defined for only links, and hence, the server will need to compose the link metrics to obtain path metrics used in services such as the Cost Map Service. In this definition, we define

the metrics to be independent of link or path, considering that future ALTO extensions may define link-based services, and hence the defined metrics should still be usable.

3. Cost Metric: OWDelay

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 unit is specified in the query context (e.g., PID to PID, or endpoint to endpoint); and the temporal unit is specified as the measurement interval in the query context.

Method of Measurement or Calculation:

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

Units of Measurement:

See section 7.4.4 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 8.3.5 of [I-D.ietf-ippm-initial-registry] for Measurement Timing.

Use and Applications:

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

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" : "delay"},
  "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" : "delay"
     }
   },
    "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: PDV

Metric name:

Pakcet 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 unit is specified in the query context (e.g., PID to PID, or endpoint to endpoint); and the temporal unit is specified as the measurement interval in the query context.

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.

Measurement Timing:Use and Applications:

See section 3 for use and application.

```
Example 2: Delayjitter 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
         }
      }
   }
```

5. 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 unit is specified in the query context (e.g., PID to PID, or endpoint to endpoint); and the temporal unit is specified as the measurement interval in the query context.

Method of Measurement or Calculation:

See section 2.2, Computation of metrics.

Units of Measurement:

The unit is percentile.

Measurement Point(s) with Potential Measurement Domain:

See section 2.1, Data sources.

Measurement Timing:

See section 2.1, second paragraph for Measurement Timing.

Use and Applications:

See section 3 for use and application.

```
  Example 3: 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,
                                }
               }
   }
```

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 prtocols 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: Bandwidth

Metric name:

Bandwidth

Metric Description:

To specify spatial and temporal aggregated bandwidth over the specified source and destination. The spatial aggregation unit is specified in the query context (e.g., PID to PID, or endhost to endhost); and the temporal unit is specified as the measurement interval in the query context.

This is just a definition of a class of cost metric 'bandwidth'. The use of this cost metric is always in conjunction with what it represents, which could be Max Bandwidth (maxbw), Residual Bandwidth (residuebw) etc.

Method of Measurement or Calculation:

See section 2.2, Computation of metrics.

Units of Measurement:

The units are bytes per second.

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.

8. Cost Metric: Maximum Bandwidth

Metric name:

Maximum Bandwidth

Metric Description:

To specify spatial and temporal maximum bandwidth over the specified source and destination. The values correspond to the

maximum bandwidth that can be used (motivated from RFC 3630 Sec. 2.5.6.). The spatial aggregation unit is specified in the query context (e.g., PID to PID, or endhost to endhost); and the temporal unit is specified as the measurement interval in the query context.

Method of Measurement or Calculation:

See section 2.2, Computation of metrics.

Units of Measurement:

See definition for the Bandwidth Cost Metric.

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 5: maxbw 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":  "maxbw"},
   "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": "maxbw"
           }
    },
"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. Cost Metric: 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); and the temporal unit is specified as the measurement interval in the query context.

Method of Measurement or Calculation:

See section 2.2, Computation of metrics.

Units of Measurement:

See definition of the Bandwidth Cost Metric.

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 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,
                           }
          }
}
```

10. 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 unit is specified in the query context (e.g., PID to PID, or endpoint to endpoint); and the temporal unit is specified as the measurement interval in the query context.

Method of Measurement or Calculation:

See section 2.2, Computation of metrics.

Units of Measurement:

See definition for the bandwidth Cost Metric.

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 7: 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,
    }
  }
}
```

11. Cost Metric: 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); and the temporal unit is specified as the measurement interval in the query context.

Method of Measurement or Calculation:

See section 2.2, Computation of metrics.

Units of Measurement:

See definition of the general Bandwidth.

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 8: 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,
                      }
        }
}
```

12. Cost Metric: 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 unit is specified in the query context (e.g., PID to PID, or endpoint to endpoint); and the temporal unit is specified as the measurement interval in the query context.

Method of Measurement or Calculation:

See section 2.2, Computation of metrics.

Units of Measurement:

See definition of the general Bandwidth.

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 9: availbw 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":  "numeric",
   "cost-metric":  "availbw"},
    "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": "numeric",
          "cost-metric": "availbw"
         }
   },

  "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],
                       }
         }
  }
```

13. Cost Metric: 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 unit is specified in the query context (e.g., PID to PID, or endpoint to endpoint); and the temporal unit is specified as the measurement interval in the query context.

Method of Measurement or Calculation:

See section 2.2, Computation of metrics.

Units of Measurement:

See definition of the general Bandwidth.

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 10: 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,
                        }
         }
}
```

14. 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 and 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. One 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.

15. IANA Considerations

IANA has added the following entries to the ALTO cost map Properties registry, defined in Section 3 of [RFCXXX].

Namespace	Property	Reference
	owdelay	[RFCxxxx], Section 3
	pdv	[RFCxxxx], Section 4
	pktloss	[RFCxxxx], Section 5
	hopcount	[RFCxxxx], Section 6
	bandwidth	[RFCxxxx], Section 7
	maxbw	[RFCxxxx], Section 8
	maxresbw	[RFCxxxx] Section 9
	rtt	[RFCxxxx], Section 10
	residbw	[RFCxxxx], Section 11
	availbw	[RFCxxxx], Section 12
	utilbw	[RFCxxxx], Section 13

16. References

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16.2. Informative References

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