ALTO Traffic Engineering Cost Metrics
draft-wu-alto-te-metrics-06

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 defined only a single cost metric, i.e., the generic
   "routingcost" metric (Sec. 14.2 of ALTO base specification [ALTO]).

   In this document, we define eleven Cost Metrics, derived from OSPF-TE
   and ISIS-TE, to measure network delay, jitter, packet loss, hop
   count, and bandwidth. The metrics defined in this document provide a
   relatively comprehensive set of Cost Metrics for ALTO focusing on
   traffic engineering (TE). Additional Cost Metrics such as financial
   cost metrics may be defined 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

   This Internet-Draft is submitted in full conformance with the
   provisions of BCP 78 and BCP 79.

   Internet-Drafts are working documents of the Internet Engineering
   Task Force (IETF). Note that other groups may also distribute

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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 define eleven cost metrics,
   listed in Table 1, to support the aforementioned applications.
   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             |
+-----------+--------------+-----------------------+
|           | delay        | [RFCxxxx], Section 3  |
|           | delayjitter  | [RFCxxxx], Section 4  |
|           | pktloss      | [RFCxxxx], Section 5  |
|           | hopcount     | [RFCxxxx], Section 6  |
|           | bandwidth    | [RFCxxxx], Section 7  |
|           | maxbw        | [RFCxxxx], Section 8  |
|           | maxresbw     | [RFCxxxx], Section 9  |
|           | unresdbw     | [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 defined in
   this document. 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 defining 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.

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 defined 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 defined
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 define in this document.

2.2. Computation of metrics

An ALTO server process 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 defining 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. The Measurement Interval(s) of the data sources
can be different from the interval that this document defines the
metric. Hence, an ALTO server needs to resolve the mismatch, when it
happens. [TODO: Need more specification.]

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: Delay

Metric name:

   Delay

Metric Description:

   To specify spatial and temporal aggregated delay 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 2.2, Computation of metrics.

Units of Measurement:

   The unit is microsecond.

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:

   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",
       "ipv4:203.0.113.45"
     ]
   }
}

 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,
         "ipv4:203.0.113.45"  : 30,
      }
    }
 }
```

4. Cost Metric: Delay Jitter

Metric name:

Delay jitter

Metric Description:

   To specify spatial and temporal aggregated jitter (latency
   variation) 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 microsecond.

Measurement Point(s) with Potential Measurement Domain:

   See section 2.1, Data sources.

Measurement Timing:

   See section 2.1, second paragraph 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",
         "ipv4:203.0.113.45"
       ]
     }
   }
   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
             "ipv4:203.0.113.45" : 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",
        "ipv4:203.0.113.45"
      ]
    }
  }
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,
          "ipv4:203.0.113.45" : 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.

   [Editor Note: Need to specify which level (AS, IP perhaps),
   details TBD for multiple-layer aspect.]

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",
           "ipv4:203.0.113.45"
         ]
       }
     }
   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,
              "ipv4:203.0.113.45" : 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",
        "ipv4:203.0.113.45"
      ]
   }
 }

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,
         "ipv4:203.0.113.45":  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",
           "ipv4:203.0.113.45"
         ]
       }
     }
   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,
             "ipv4:203.0.113.45":  5000,
                           }
             }
   }
```

10. Cost Metric: Unreserved Bandwidth

   Metric name:

      Unreserved Bandwidth

   Metric Description:

To specify spatial and temporal unreserved bandwidth over the
specified source and destination. The values correspond to the
bandwidth that can be reserved with a setup priority of 0 through
7. Therefore this metric is endcoded as an array of 8 values.
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: unresbw value on source-destination endpoint pairs
In this example, the Collection method specifies that the
'unresbw' values are defined as the 'unavailable bandwidth' specified
in section 2.5.8 of RFC3630: 8 unavailable bandwidth value are
reported in the same OSPF message using the same TLV. Each value
is corresponding to the bandwidth that can be reserved with a setup
priority of 0 through 7.

```
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":  "unresbw[1,8]" },
   "endpoints":   {
      "srcs": [ "ipv4:192.0.2.2" ],
      "dsts": [
        "ipv4:192.0.2.89",
        "ipv4:198.51.100.34",
        "ipv4:203.0.113.45"
      ]
    }
  }

HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
{
    "meta": {
          "cost-type": {
          "cost-mode": "numerical",
          "cost-metric": "unresbw[1,8]"
        }
   },
  "endpoint-cost-map" {
          "ipv4:192.0.2.2" {
          "ipv4:192.0.2.89" :   [0,0,0,0,0,0,0,0],
          "ipv4:198.51.100.34": [0,0,0,0,0,0,0,2000],
          "ipv4:203.0.113.45":  [0,0,0,0,0,0,0,5000],
                         }
       }
}
```

[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 [I-D. ietf-isis-te-metric-extensions], 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",
        "ipv4:203.0.113.45"
      ]
    }
  }

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,
          "ipv4:203.0.113.45":  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
[I-D. ietf-isis-te-metric-extensions], 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",
        "ipv4:203.0.113.45"
      ]
   }
     }

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],
           "ipv4:203.0.113.45" : [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
   [I-D. ietf-isis-te-metric-extensions], 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",
         "ipv4:203.0.113.45"
      ]
    }
 }


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,
        "ipv4:203.0.113.45" :  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             |
    +-----------+--------------+-----------------------+
    |           | delay        | [RFCxxxx], Section 3  |
    |           | delayjitter  | [RFCxxxx], Section 4  |
    |           | pktloss      | [RFCxxxx], Section 5  |
    |           | hopcount     | [RFCxxxx], Section 6  |
    |           | bandwidth    | [RFCxxxx], Section 7  |
    |           | maxbw        | [RFCxxxx], Section 8  |
    |           | maxresbw     | [RFCxxxx] Section 9   |
    |           | unresdbw     | [RFCxxxx], Section 10 |
    |           | residbw      | [RFCxxxx], Section 11 |
    |           | availbw      | [RFCxxxx], Section 12 |
    |           | utilbw       | [RFCxxxx], Section 13 |
    +-----------+--------------+-----------------------+
```

16. References

16.1. Normative References

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16.2. Informative References

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